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REPORT
of the
FERTILIZER PRODUCTION COMMITTEE

VOL. I—REPORT AND ANNEXURES

CONTENTS

REPORT

ANNEXURES

The Fertilizer Map referred to in the Report (please see Annexure IV) has not been printed.

CHAPTER I—INTRODUCTION

We were appointed under the Production Ministry's Resolution No. Fy.I-17(1)/54 of the 29th October 1954 of which a copy is reproduced in Annexure I. After setting out the conclusion that facilities should be established by the year 1961 so as to augment the present capacity of indigenous production of nitrogenous fertilisers by an additional 170,000 tons of nitrogen per year, the resolution laid down our terms of reference as follows:—

"(1) To suggest possible locations for the new fertiliser factories for the production of ammonium sulphate, ammonium sulphate-nitrate and urea having regard to all relevant considerations including adequacy of transport and the proximity of consumer points;

(2) To indicate the quantities of one or more of these fertilisers that could be produced at each location on an economic basis, the processes to be adopted and the probable cost of production;

(3) To estimate roughly the capital and working cost of the plants recommended at the different locations;

(4) To make recommendations regarding the requirements and the provision of technical personnel for staffing the new plants; and

(5) To suggest the best method of further processing the Committee's recommendations."

Two of us, Shri B. C. Mukharji and Shri K. C. Sharma, were appointed as whole-time members of the Committee; the former took over charge of his duties on the 25th October 1954 and the latter on the 1st November 1954.

2. Shortly after our Committee was set up a subsidiary task of some magnitude, unconnected with our official terms of reference, was assigned to three of us, that is, the two whole time members and Dr. A. Nagaraja Rao. The assignment related to the Sindri Expansion Scheme and took us quite two months to complete. Two reports on the expansion scheme were submitted to the appropriate authorities on the 5th December 1954 and on the 3rd January 1955.

3. Soon after the first meeting of the Committee, we invited, as an essential preliminary step, suggestions and proposals from the various State Governments, indicating possibilities of economic production of nitrogenous fertilisers and advantageous location of new fertiliser production units in their respective States. We have received, in response to this invitation, self-contained memoranda from the following State Governments:

(i) Travancore-Cochin;

(ii) Mysore;

(iii) Madras;

(iv) Andhra;

(v) Orissa;
(vi) West Bengal;
(vii) Assam;
(viii) Bihar;
(ix) Uttar Pradesh;
(x) PEPSU;
(xi) Rajasthan;
(xii) Madhya Pradesh;
(xiii) Vindhya Pradesh;
(xiv) Hyderabad;
(xv) Bombay; and
(xvi) Saurashtra.

Copies of the memoranda received from State Governments, which have been discussed in some detail in a subsequent Chapter, are* appended (Appendix I).

4. Apart from State Governments' proposals, we have received valuable suggestions from a number of commercial and business organisations all of which have received our earnest consideration. We have made a selection of the more important memoranda received from non-official sources and reproduced them in Appendix II.

5. On a preliminary examination of the proposals received from State Governments and other bodies it became apparent that it would be necessary for the Committee to undertake a countrywide tour for the satisfactory completion of the task assigned to it. The Committee felt it essential, in particular, to investigate on the spot, in consultation with the representatives of State Governments concerned and others, the suggestions received by it about potentialities of economic production of nitrogenous fertilisers at different locations widely distributed all over the country. A statement is annexed (Annexure II) showing the places visited by the Committee with the dates of visit.

Most of the touring was done by the two whole-time members since in the exigencies of work it was not possible for the other two members to spare the necessary time. For the accuracy of the factual data and materials collected during the Committee's tours and, more particularly, for the factual observations and conclusions recorded in Chapters III and IV, the Chairman and the other whole-time member accordingly accept the entire responsibility.

6. The first meeting of the Committee was held on the 1st November 1954 and the last meeting on the 2nd/3rd May 1955 when our conclusions and recommendations on all important issues were formulated. In between these dates we met on 21 other occasions either for conferring with officials or representatives of State Governments or other persons and parties interested in our investigations or for discussion among ourselves. The proceedings of all the 23 meetings are enclosed (Appendix III).

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* For the sake of convenience all Appendices—as distinguished from Annexures—have been placed in a separate volume.

7. We owe a deep debt of gratitude to the Governments of the States where we had occasion to tour for local investigations. Everywhere we were afforded whatever facilities we needed for the success of our tours and the utmost assistance in the collection of factual data. We are equally grateful to those representatives of State Governments who took the trouble of accompanying us on our tours much of which had to be done under somewhat trying conditions. We are indebted to them for the readiness with which they collected data and materials for us and placed their local knowledge at our disposal.

We wish to tender our thanks also to a great many private gentlemen as well as business organisations and non-official bodies for the help and hospitality we have received from them. We greatly appreciate the courtesy of many of them in spending long hours, which they could ill afford to spare, for showing us round factories, workshops and other places of interest and for discussing with us problems of common interest.

To the various Government departments including the Railway Board and the Central Water and Power Commission, whose help we had unavoidably to seek, we owe a special debt of gratitude. We are, in particular, beholden to the officials of the Ministry of Agriculture with whom we had to take frequent counsel at all stages of our investigations. Their advice and guidance on matters pertaining to agricultural technique, methods and practices have, we gratefully acknowledge, always been readily and abundantly accorded. We are equally indebted to the officers of the Atomic Energy Commission and the officers in charge of Bhakra Dam Design and Construction for their cordial co-operation in our investigation of the problems relating to the Nangal project.

We wish to express our indebtedness to Dr. M. S. Patel of Santa Cruz, Bombay for the many valuable suggestions we have received from him and the ready manner in which he was good enough to place at our disposal carefully collected and verified information on many matters of interest to us; and to Shri H. N. Ganguli of Bikaner Gypsums Limited for carrying out efficiently and expeditiously the special task, which he gladly undertook on our request, of investigating the potentialities of Trichinopoly gypsum reserves.

We had many occasions to seek the assistance of Messrs Sindri Fertilizers and Chemicals Limited and we wish to mention particularly a special assignment which Dr. K. R. Chakraborty, the Chief Technologist, and his colleagues carried out for us with the permission of the Managing Director. The assignment related to the determination of the suitability of various alternative non-alkaline diluents of ammonium nitrate, an intriguing problem for the solution of which the credit is largely due to the Sindri Technological Organisation.

We would like, in the end, to record our appreciation of the devoted work which our small secretariat staff has done and would mention in particular, the services rendered by Mr. Vishwanathan, one of the Sindri Technologists who was on deputation with us for over two months and greatly helped us during this period in checking up technical data and making numerous cost calculations. Our Secretary, Mr. P. M. Nayak, I.C.S. has discharged his duties with

zeal and efficiency and has not only been a most useful link between the Committee and the Government but has rendered us valuable assistance as well in looking after our correspondence, collecting data and materials, recording the minutes of our proceedings and arranging our tours, some of which he was able to attend personally despite his preoccupation with his own duties in the Ministry of Production.

8. We append a summary of our recommendations in Annexure XV. We have divided the summary into two parts: in the first part we have summarised those of our recommendations which alone, strictly speaking, come within the scope of our terms of reference; the second part summarises such of our recommendations as must be regarded as only incidental and ancillary.

CHAPTER II—PRODUCTION TARGETS

(1) TOTAL AND ZONAL REQUIREMENTS OF NITROGEN

We are required by our terms of reference to arrange for the establishment, at the best possible locations, of a total production of 170,000 tons of nitrogen in the form of one or other of the following nitrogenous fertilisers: (a) ammonium sulphate; (b) sulphate-nitrate; and (c) urea. In recommending suitable locations we are to have regard to, among other considerations, "proximity of consumer points".

2. Along with our terms of reference we received, however, a directive that one of the new fertilizer production units will have to be set up in the Bhakra-Nangal area in conjunction with a project for production of heavy water. We considered accordingly in advance the problems relating to a combined heavy water *cum* fertilizer project at Nangal; and since in the interest of its early execution, it seemed necessary to take in hand certain measures without delay, we submitted an interim report on the 22nd January which is reproduced in Annexure III. Our interim recommendations were that if a nitrogen fixation plant is to be set up at Nangal and associated with manufacture of heavy water (i) its nitrogen output should be of the order of 70,000 tons per year in order that economic production can be ensured; (ii) the process for ammonia synthesis to be adopted at the plant should be based on electrolytic decomposition of water and liquefaction of air; and (iii) the end product should be a suitable type of ammonium nitrate fertiliser*, even though our terms of reference restrict our choice to urea, ammonium sulphate and sulphate-nitrate. We have in this report dealt with the Nangal project in greater detail at the appropriate places and have endeavoured to fill in the rather incomplete picture in our interim recommendations. We wish here only to draw attention to our proposal that the Nangal plant should have a production capacity of 70,000 tons of nitrogen per year. This recommendation, which we understand has since been accepted by Government, resolves our task to one of recommending a plant or plants for the production of 100,000 tons of nitrogen per year at some other suitable centre or centres.

3. We understand that the three selected types of nitrogenous fertilisers mentioned in our terms of reference as well as the total quantity in which they are to be produced, in terms of nitrogen, were specified in consultation with, and largely on the advice of, the Ministry of Agriculture. Almost immediately after our Committee was set up we received from that Ministry "a fertiliser plan for 1956-61" and certain notes illustrated by a map explaining the fertiliser requirements, in terms of both quantities and types of fertilisers, of different regions in India in the light of such factors as the nature of soils, crops normally grown and general climatic conditions. The notes and the map received from the Ministry which are annexed (Annexure IV) will indicate, firstly, the Agriculture

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* From certain papers which we received along with our terms of reference we understood that it would be permissible to consider a suitable type of ammonium nitrate fertiliser for the Nangal plant. This conforms also to the view of the Agriculture Ministry indicated in their "Fertiliser Map of India"—See Annexure IV.

Ministry's estimate of annual consumption of nitrogen in the country by 1960-61; secondly, the regional distribution of the total anticipated nitrogen consumption; and thirdly, the requirements of different types of nitrogenous fertilisers in different regions. The data furnished by the Ministry are extremely valuable and we proceed to discuss below in some detail the conclusions we have been able to draw from them.

4. The Agriculture Ministry's estimate of total requirement of nitrogen by the year 1960-61 is 373,000 tons. We understand that the production target of 170,000 tons of nitrogen fixed in our terms of reference, has been arrived at by deducting from the total requirement existing capacity of nitrogen production in the country (computed to be 120,000 tons) and then taking two-thirds of the balance as the level of new production to be achieved by 1960-61. The existing capacity computed at 120,000 tons takes into account, we understand, expansion of the Sindri factory at a time when the expansion scheme contemplated the processing of 6 m.cu.ft. of coke oven gas to make about 110 tons of ammonia (and not the entire quantity of 10 m.cu.ft. of gas which it has more recently been decided to utilise for ammonia synthesis); but does not include expansion of the Alwaye factory recommended by another Committee whose report submitted in August 1954 is before Government.

5. The Agriculture Ministry's fertiliser map (Annexure IV) will show that the Ministry has divided up the country into three zones* on the basis of similarity of soils, crops and climatic conditions and has allocated between them the estimated gross requirement of nitrogen in the following manner:—

Zone I	..	1,13,500 tons
Zone II	..	75,600 tons
Zone III	..	1,83,900 tons

Since the "existing production" is entirely in Zone III, the net requirements of different zones which it should be our aim to meet by new production is as follows:—

Zone I	..	Two-thirds of 1,13,500 tons	= 75,666 say 76,000 tons
Zone II	..	Two-thirds of 75,600 tons	= 50,400 say 51,000 tons
Zone III	..	Two-thirds of difference between 1,83,900 and 1,20,000 tons	= 42,600 or 43,000 tons
		Total ..	1,70,000 tons

6. Except for Zone III, zonal allocations made by the Ministry of Agriculture on the basis explained in the last paragraph seem to fit

*The three zones comprise the following areas:

Zone I—the States of Jammu & Kashmir, Himachal Pradesh, the Punjab, PEPSU, Delhi, U.P. and the northwestern portion of Rajasthan commanded by the Bhakra-Nangal irrigation system.

Zone II—the rest of Rajasthan and States of Ajmer, Madhya Bharat, Vindhya Pradesh, Madhya Pradesh, Bhopal, Saurashtra, Kutch, Bombay and Hyderabad.

Zone III—the States of Mysore, Coorg, Travancore-Cochin, Madras, Andhra, Orissa, Bihar, West Bengal, Assam, Tripura and Manipur.

in also with the point of view of distribution facilities in the sense that a production centre located at a convenient place in any zone would be a convenient supply and distribution centre for it as well. This conclusion does not hold good in respect of Zone III which extends from the Eastern Himalayas in Assam to Cape Comorin in Travancore-Cochin. Further, most of the "existing production" of nitrogen is centralised at Sindri far away from areas* included in the southern portion of the zone. In order to bring out a clearer picture of regional demands and compare them with regional production, we have subdivided Zone III into two independent zones which we shall hereafter refer to as Zone IIIA and Zone IIIB, the dividing line between the two zones being the boundary between Orissa and Andhra States. We include all areas to the north of this line in Zone IIIA and all areas to the south in Zone IIIB. On this basis the requirement of Zone IIIB, according to the Agriculture Ministry's estimate, comes to 1,04,500 tons of nitrogen against which we have to adjust the existing production at Alwaye and Belagula. After doing so, on the basis of the designed capacity† of the two factories, we conclude that the net additional requirement of Zone IIIB is about 94,500 tons of nitrogen, two-thirds of which is 63,000 tons. This is 20,000 tons in excess of the additional requirement of Zone III as a whole which means that to this extent there is "over production" in Zone IIIA as compared with the requirements of that zone.

7. We wish to make it clear that we do not use the term "over production" in a deprecatory sense. We do so merely to indicate the relationship of regional production with regional demand in the context of the Agriculture Ministry's plan of division of the country in different zones. We are aware, of course, that the quantum of production in Zone IIIA was deliberately planned on the advice of the Technical Mission appointed by Government in 1944 with a view to secure the economic advantages of large-scale production of ammonium sulphate in a single production unit at a location having certain overall advantages. We consider that this centralisation of production was a sound plan and has not only produced overall economy but also other fruitful results in many directions. We do not, by any means, propose to advocate the view that production and distribution should now be localised, that regional production must be established, whatever the advantages or disadvantages, to meet regional demands. On the contrary, we take the view that in fixing locations and sizes of plants our main objective should be to reach nitrogen to the cultivator at the cheapest possible cost. Other factors of importance being more or less equal, the consideration that, we think, should prevail is maximum overall economy in both production and distribution. Production economies are undoubtedly the more important and significant factor since (i) it is always more expensive to transport raw materials rather than finished products; and (ii) the cost of utilities like power and water and of raw materials like gypsum and coal differs greatly at different locations according to the nearness of their sources and the ease with which they can be made available. Nevertheless, the factor of distribution costs of

* These areas are some of the largest consumers of fertilisers today.

† The designed capacity of the Belagula pilot plant is 6600 tons of ammonium sulphate per year. Although the designed capacity of the Alwaye factory is 44,640 tons of ammonium sulphate a year, the maximum production that has so far been achieved in any year is only 31,726 tons.

the end-product is one which has obviously to be fully taken into account and can make, in given circumstances, a significant difference in overall economy, that is, in the total cost of fertiliser as delivered to the cultivator of the particular areas where it is required. As will appear later, it has been our endeavour, in recommending locations for the new factories as also their size and production capacity, to take adequate account of both production and distribution economies.

8. A further point we would like to emphasize in this connection is that though in our subsequent discussions we have followed the Agriculture Ministry's plan of division of the country into "zones", subject to the modification indicated in para 6, we have done so merely as a convenient method of estimating and indicating nitrogen requirements of different States, areas and regions in terms of one or the other of the three fertilizers specified in our terms of reference. Some such assessment of "zonal" or regional requirements is in our view necessary in order that we may have a fairly clear picture of the main consumer points where the new production to be established under the present expansion programme will have to be delivered. It will, we hope, be appreciated that beyond serving as a helpful and convenient means of achieving this limited objective, "zones" have no real significance.

(2) REQUIREMENTS IN TERMS OF SPECIFIED NITROGENOUS FERTILISERS

9. We next proceed to examine the Agriculture Ministry's estimated requirements, in terms of different types of fertilizers, for different regions. In recommending different fertilizers for different regions, the more important factors which the Ministry has taken into account are:

(a) suitability from the point of view of soils and crops;

(b) suitability from the point of view of climatic conditions; and

(c) ease of handling and application and freedom from hazards and generally acceptability to farmers.

Subject to the above the Ministry has been guided by the consideration that the aim should be to make available to the cultivator nitrogen in the cheapest possible form. As far as cost of production and economy in transport go, the Agriculture Ministry's assumption appears to be that ammonium sulphate is the most expensive type of nitrogenous fertilizer. It is, in their view, somewhat more expensive than double salt and considerably more so than ammonium nitrate and urea, the latter being the cheapest of these four types of nitrogenous fertilizers. Generally speaking, this assumption is correct, presuming, of course, identical production conditions and parity in the matter of such factors as nearness to sources of main raw materials, cost of water, power and other utilities etc. One good reason why ammonium sulphate should be more expensive per unit of nitrogen than either ammonium nitrate or nitro-limestone or urea is that it involves the processing of, besides coal (which is the common raw material for all these products), another relatively expensive material, that is, sulphur or pyrites or gypsum. Besides coal, nothing else is required for ammonium nitrate or urea; and the second raw material, limestone of the quality required for making nitro-limestone, is easily obtainable and relatively inexpensive.

10. With regard to the three main factors which have led to the selection of different types of fertilizers for different areas, our discussions with the Ministry of Agriculture have clarified the position as follows:—

(a) *Suitability from the point of view of soils and crops*

We have been told that ammonium sulphate is suitable for all types of soils except acid soils, most of which are in Zone III. Urea and double salt are suitable for all soils. Ammonium nitrate treated with the usual diluent i.e. chalk, is suitable for all soils except the calcareous soils of the Punjab and its adjoining areas in the north. All these fertilisers are suitable for all crops except that, we have been told, it would be wasteful to apply ammonium nitrate (suitably diluted so as to eliminate explosion hazards and improve its keeping quality) to the paddy crop in the early stages of its growth.

(b) *Suitability from the point of view of climatic conditions*

Climatic conditions, according to the Ministry of Agriculture, have to be considered from two different angles; (a) in so far as they affect the keeping quality of different fertilisers; and (b) in so far as they condition beneficial use of any given type of fertiliser. Our discussions with the Ministry of Agriculture have made it clear that ammonium sulphate is a suitable fertiliser everywhere viewed from either angle and the same is true of double salt. Ammonium nitrate (with usual dilution) is unsuitable for areas of high humidity from the point of its keeping quality; otherwise its use is beneficial everywhere irrespective of climatic conditions. Urea is unsuitable, considered from angle (a), for areas of high humidity; and it is also unsuitable, from angle (b), for areas of heavy and unpredictable rainfall.

(c) *Ease of application and handling and freedom from hazards; acceptability to farmers*

In regard to this point, ammonium sulphate no doubt scores over every other type of nitrogenous fertiliser in the present state of development of our agricultural practices. On the other hand, there is no such difficulty about the application or handling of any other type of fertiliser as cannot be removed, given time and a reasonable opportunity for the investigation of the problem. The Ministry of Agriculture are, further, prepared to propagate the use of new fertilisers and create the necessary demands in advance so as to ensure their acceptability to farmers.

11. After balancing the various factors discussed in the last two paragraphs, the Ministry of Agriculture has made the recommendations indicated in the map and the accompanying notes in Annexure IV. In doing so they have done their best to solve a number of awkward problems; and it is also obvious that they have made a number of compromises in order to reach practical solutions. The following, in particular, are worthy of mention:

(1) While ammonium sulphate is, in the view of the Ministry of Agriculture, not a very suitable fertiliser for the rice-growing areas in the south and the east (represented mostly by Zone III), because of the acid nature of soils in this region, it is, from another point of view, ideal for these areas which are also areas of high humidity because

it has the most satisfactory keeping quality. The Ministry of Agriculture has attached overriding importance to the latter factor and, for the time being, ignored the objection to the application of ammonium sulphate to acid soils.

(2) Nitro-chalk or nitro-limestone with the usual percentage of nitrogen (20.5) should, in the view of the Ministry of Agriculture, be ruled out altogether from the country, because it does not suit climatic conditions in wet areas, though it does suit the soils and crops there; and it does not suit the calcareous soils in dry areas, though in these areas it is pre-eminently suitable from the point of view of climatic conditions and crops grown.

(3) Although urea is an excellent all-purposes fertiliser, its use has at present to be confined, until more experience is available, to relatively dry areas with controlled irrigation (controlled irrigation in this context being construed to mean also reasonably predictable rainfall) because of its comparatively poor keeping quality and its tendency to leach out during the first few days (or hours) of its application in case of sudden and heavy rainfall.

12. While we do not intend to dispute the reasonableness of the conclusions reached by the Agriculture Ministry's experts, we would suggest that in the selection of fertilisers suitability for soils and crops is a more important factor than keeping quality; and if a compromise has to be made, greater importance should be attached to the former factor. Despite this reservation, however, we have considered it proper to formulate our plans in accordance with the Agriculture Ministry's views, particularly as our choice of fertilisers is restricted to urea, ammonium sulphate and sulphate-nitrate, apart from suitably diluted ammonium nitrate for Nangal. Though we have restricted our consideration to the three fertilisers specified above, we would venture to suggest that, when the next instalment of expansion of indigenous production of artificial fertilisers is planned, attention should be paid to such alternative products as may be cheaper sources of essential plant nutrients. In particular, consideration should be given to the following propositions which have been brought to our notice by knowledgeable individuals and parties, both Indian and foreign:

(a) We suggest that the potentialities of nitro-limestone in Indian conditions deserve further study. We would point out that nitro-limestone is a relatively cheap source of nitrogen (assuming, of course, its manufacture in close vicinity of limestone deposits); and it is also the most preferred fertiliser in Europe. Even if the objections to its application to the calcareous soils of the north be fortified and confirmed as a result of further expert investigation, it should not, in our view, be beyond scientific ingenuity to discover ways and means of imparting to it satisfactory enough keeping quality by proper treatment so as to render it suitable for use in the humid regions in the south and the east.

(b) We suggest also that the feasibility of manufacturing ammonium phosphate and nitro-phosphate in this country should be fully explored. Our terms of reference do not

permit us to consider phosphatic fertilisers at all, but in the course of our investigations it has been repeatedly brought to our notice that development of phosphatic fertilisers should proceed side by side with the development of nitrogenous fertilisers and that there are large tracts in India where soils are significantly deficient in phosphorus. It has been urged, therefore, that as a matter of long-term planning for improvement and conservation of soil fertility, Indian soils should be treated with a mixture of phosphorus and nitrogen, even though application of phosphorus may not yield the same spectacular results and bring about the same immediate gain as application of nitrogen. Phosphatic rocks would naturally have to be imported into India, but that should not be regarded as a valid objection to the establishment of facilities for indigenous production of phosphatic fertilisers for areas where treatment of soils with phosphorus would mean, according to expert opinion, their long-term beneficiation. A great advantage of both ammonium phosphate and nitrophosphate is their satisfactory keeping quality under humid conditions. In this respect these products are comparable to ammonium sulphate but, as equally good sources of nitrogen, they should be preferred to ammonium sulphate particularly if it is produced from imported gypsum or sulphur or pyrites. In either case one of the principal raw materials will have to be imported; but while the sulphur content of ammonium sulphate would confer little or no benefit on soils (it may actually be harmful for them if they are acid soils), in the other case the residual phosphates, after nitrogen is fixed in the soil, would be a soil conditioner and plant nutrient of great value.

(c) We suggest that consideration should be given to the manufacture and utilisation of another type of nitrogenous fertiliser, that is, ammonium chloride. Its advantages are that it is particularly suitable for calcareous soils; and secondly, that it can, under favourable circumstances, be associated with the manufacture of soda ash for which the country is, we understand, in great need at the moment. We refer in this connection to the West Bengal Government's memorandum where a great deal of evidence has been furnished to indicate its highly beneficial use in certain circumstances and for a great many crops and also its extensive production and increasing use in many countries in the world today. We draw attention, also, to the great deal of information furnished in the memorandum presented to us by Sahu Chemicals Ltd. (App. II) during our visit to Dalmianagar on the 27th March with regard to the suitability of ammonium chloride as an all-purposes fertiliser and the potentialities of its extensive use in Indian conditions. The carefully collected literature incorporated in the memorandum shows (i) firstly, that ammonium chloride is, according to experience elsewhere in the world, suitable for all crops except tobacco, citrus fruits, potatoes and certain other starch-forming plants. It is quite suitable in any case for the main cereals grown in India, such

as, rice, wheat, maize, etc.; (ii) secondly, that though ammonium chloride in its pure form (26 per cent Nitrogen) has acid reaction, the acidity produced in the soil is more easily washed away than the acidity produced by ammonium sulphate. If the nitrogen content is brought down by admixture of lime to 20.5 per cent, the end product would produce less acidity than ammonium sulphate having equivalent nitrogen content. If the admixture of lime is enhanced so as to bring down the nitrogen content to about 16 per cent, the behaviour of the product would be completely neutral; and (iii) thirdly, that while the keeping quality of ammonium chloride in its pure state is not as good as that of ammonium sulphate, it is immeasurably better than that of ammonium nitrate. With even enough admixture of lime to bring down the nitrogen content to 20.5 per cent, the keeping quality of the mixed product is said to be distinctly superior to that of ammonium sulphate having the same nitrogen content. These claims seem to be supported by reliable evidence and deserve, we suggest, the consideration of the Ministry of Agriculture. We accordingly commend for consideration the suggestion that experiments with ammonium chloride, both in a pure form as well as in admixture with lime in varying proportions, might be carried out and an effort made to ascertain its suitability for Indian crops in the context of Indian climatic conditions.

(d) We would urge that greater use should be made of urea than is contemplated under the present expansion programme. At practically all the places and in all regions, dry or humid, which we have visited, we have had the most encouraging reports of the results of its experimental use which the Ministry of Agriculture has initiated in recent years. In view of the limited use of urea contemplated in the present programme, we have suggested that a urea plant should be invariably associated with either an ammonium sulphate or a sulphate-nitrate plant so that it is possible to adopt the "once through" process and avoid recycling of unreacted gases. With more extensive use of urea and its gradual substitution for the older and more orthodox type of nitrogenous fertilisers, such as ammonium sulphate, the adoption of the "once through" or even the "partial recycling" process for manufacture of urea will not always be possible. We suggest accordingly that the next expansion programme should definitely contemplate establishment of urea production using the recycling method (both partial *and* complete) in advance of which arrangements may be set in train for the exploration of suitable processes and technique in India and the necessary training of Indian technical personnel.

(e) Lastly, we would advocate that a start be made with popularising the application of liquid or aqueous ammonia as a fertiliser. To begin with, this may be done in selected areas where agricultural practices are already advanced to some extent, as, for example, in Mysore, where the

Minister of Agriculture himself is an enthusiastic supporter of direct use of ammonia as the cheapest known source of nitrogen today. Even in areas where direct application of ammonia may not be considered a practical proposition at present, use of ammonia as such may still be possible if facilities are established for the manufacture of ammoniated superphosphate.

13. We hope that it would be possible to secure the production of some or all of the end-products discussed in the preceding paragraph, along with increased production of urea, in the next plan for expansion of indigenous production of chemical fertilisers. We would like to take the opportunity to draw pointed attention to the fact that our gypsum resources, though considerable, are not unlimited; and it would be most unfortunate if sulphur or pyrites or gypsum, which in themselves have no value as plant nutrients, have to be imported merely for the purpose of fixing nitrogen—an out-worn practice which is being gradually discarded in other parts of the world.

14. Returning, however, to our present programme and taking into account our terms of reference which restrict our choice of fertilisers to ammonium sulphate and sulphate-nitrate, apart from urea, we consider that we can do no better than record our agreement with the Agriculture Ministry's estimate of the quantities in which the specified fertilisers should be produced and their indication of the regions where one or other of them can be most suitably used. We invite a reference to Annexure IV for a full statement of the Agriculture Ministry's views on the subject and their estimated requirements, both total and regional, of the specified fertilisers. The broad conclusion which we draw from these data is that in order to meet the requirements of fertilisers considered most suitable for different regions and achieve an extra production of 170,000 tons of nitrogen, facilities should be established for the manufacture of, roughly, (a) 200,000 tons of ammonium nitrate (35 per cent N) with a suitable diluent; (b) 65,000 tons of urea, (46 per cent N) and (c) 275,000 tons of sulphate-nitrate (26 per cent N) or, alternatively, an equivalent quantity (in terms of nitrogen) of ammonium sulphate, whichever of these two products it may be cheaper to make in plants of the selected size at the selected location or locations.

15. It follows from the manner in which "existing production" has been computed (para 4) that the target production of ammonium nitrate, urea and ammonium sulphate/double salt set out above leaves out of account the contemplated expansion of the Alwaye factory and also the recent decision to process 10 million cu.ft. of coke oven gas at Sindri instead of 6 m.cu.ft. of gas as originally planned. We have assumed that these two items of extra production will not count towards, or be included in, the 170,000 tons of new nitrogen production we have been asked to arrange for. We are, indeed, convinced, from what we have been able to gather in the course of our tours, that the full net demand of 250,000 tons of nitrogen assessed by the Ministry of Agriculture is very likely to materialise without difficulty by 1961. We have noticed that all State Governments are keen on popularising chemical fertilisers and are confident of creating large demands in the near future by the drive

which they have initiated with, of course, varying degrees of intensity and efficiency. We suggest, accordingly, that the expediency of restricting the present expansion programme to only two-thirds of the net requirements assessed by the Ministry of Agriculture should be examined afresh. We propose to revert to this topic once again in a later Chapter.

16. The reasons why we are recommending, in agreement with the views indicated in the Agriculture Ministry's fertiliser map (Annexure IV), that a part of the new production should be in the form of a suitable type of ammonium nitrate fertiliser even though it is not one of the fertilisers officially specified in our terms of reference have been briefly explained in our interim report on the Nangal Project (Annexure III). While dealing with the question of products and processes to be established at Nangal among other locations in Chapter VI, we have examined the point in somewhat greater detail and considered one or two other alternative products which have lately been brought to our notice. We confirm, meanwhile, the recommendation made in our interim report (Annexure III) that the entire quantity of ammonium nitrate fertiliser required for both Zones I and II amounting in all to 70,000 tons of nitrogen or 200,000 tons in terms of pure ammonium nitrate should be produced in a single unit located at Nangal.

17. A precise assessment of the zonal requirement of the balance of new production recommended i.e. 65,000 tons of urea and 275,000 tons of double salt (alternatively, equivalent ammonium sulphate) per year is a matter of some difficulty because of the need for adjusting the *"over production" in Zone IIIA. What is clear is that assuming sub-division of the Agriculture Ministry's Zone III into two separate Zones IIIA and IIIB (see para 6) and after allowing for "existing production" in them, the allocation of this new production should be between Zone II and Zone IIIB and that from the point of view of urea requirements of these two Zones, the total urea production should be split up between them roughly in the proportion of 1 : 2, production of ammonium sulphate/double salt being then conveniently allocated between the two zones in equal proportion.

18. The conclusion just set out above, like every other conclusion in this chapter, must be regarded as subject to the consideration we have urged in para 7. We emphasise once more that our estimate of zonal requirements is by no means a conclusive pointer to the suitable location or size and capacity of the new production unit or units; zonal requirement is, in our view, merely one of the many factors that have to be taken into account in determining these important issues. At this stage all that it is possible to conclude, fairly definitely, from the analysis we have made in this chapter is that:

(1) purely from the point of view of zonal requirement, the production target of 170,000 tons of nitrogen per year can be suitably allocated thus:

(a) Zone I—76,000 tons
(b) Zone II—51,000 tons
(c) Zone IIIA—minus 20,000 tons
(d) Zone IIIB—63,000 tons;

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*"over-production" is to be understood in the sense and subject to the reservations we have explained in para 7.

(2) having in view our official terms of reference, the advice we have informally received from Government and the trend of our discussions with the Ministry of Agriculture, the new production to be established under the present programme should, in terms of different types of fertilisers, be as follows:

(a) 200,000 tons of ammonium nitrate (35 per cent N) with a suitable diluent;

(b) 65,000 tons of urea;

and (c) 275,000 tons of sulphate-nitrate (alternatively, equivalent ammonium sulphate);

and (3) taking into consideration regional demands, practically the entire quantity of ammonium nitrate production is required for Zone I; two-thirds of the proposed urea production and half the ammonium sulphate/sulphate-nitrate production may appropriately be deemed as due for distribution in Zone IIIB; and the balance of urea and ammonium sulphate/sulphate-nitrate production may then be regarded as the quota for Zone II.

The foregoing confirms our conclusion that the production of the entire quantity of ammonium nitrate fertiliser can be appropriately arranged for at Nangal particularly as a nitrogen plant has anyhow to be set up there. It can further be reasonably concluded that if other factors are equal and subject always to the paramount consideration of overall economy in both production and distribution, the new production of urea and double salt should be established at a convenient location or locations in Zone II and/or Zone IIIB.

CHAPTER III—RAW MATERIALS

The main raw materials with which we are concerned, having regard to the fertilisers specified in our terms of reference, are, besides of course water and electricity, (1) coal and lignite; (2) spare and waste gases; (3) gypsum; and (4) sulphur and pyrites.

The first two of these are the chief potential sources of nitrogen and one or the other of the latter two is an essential ingredient of ammonium sulphate and, therefore, of sulphate-nitrate as well.

(1) COAL AND LIGNITE

2. Coal occurrences in India are well-known and a fair amount of information is available as regards both the extent of various reserves and the characteristics of different types of coal found in them. Reliable and authentic statistics on the subject are furnished in such useful and convenient compilations as "Indian Coals—their nature and composition" published in 1949 by the Fuel Research Committee of the Council of Scientific and Industrial Research. Many of the locations for the new fertiliser production units suggested for our consideration are near one or other of the well-known coal deposits. In discussing the potentialities of these locations we have naturally dealt with, at the appropriate places, the suitability of the nearest coal for various purposes, particularly for ammonia synthesis, and the size of its reserve. We are in no position to add usefully to the information we have furnished in that context so far as coal proper is concerned, but we would take this opportunity to record our personal observations on the lignite reserves of South Arcot in Madras and at Palana near Bikaner in Rajasthan. We do so for two reasons namely (i) direct exploitation, preferably on the spot, of lignite is now a recognised and valuable method of ammonia synthesis; and (ii) as will appear later, these two particular deposits have an important bearing on two of the most promising locations which we have had occasion to consider.

3. *South Arcot Lignite*—Although the existence of South Arcot lignite has been known for several decades, the proving of the deposits and the investigation of mining problems in relation to them are of very recent origin. Only in May 1954 the services of a firm of Consulting Engineers, the Powell Duffryn Technical Services Limited, London, were enlisted under the Colombo Plan "to prepare a project report for a programme of industrial development in the State of Madras based on the exploitation of lignite deposit at Neyveli in South Arcot district." We have carefully studied the interim report which this firm of Consulting Engineers submitted to the Government last cold weather and have also seen for ourselves the experiments and investigations now in progress at Neyveli. We would endorse the estimate of Powell Duffryn—even though the estimate is based on somewhat inadequate data, that is, the records of only one shaft and 160 boreholes put down by the Madras Lignite Investigation Organisation—that the total lignite reserve covers an area of roughly 85 sq. miles and is probably of the order of 2,000 million tons. The recorded thickness of the lignite varies from zero to 89 feet and its *least* recorded depth is about 150 feet below the surface. A site covering an area of about 5¼ sq. miles has been selected as most suitable for mining operations in the light of such favourable factors as

relatively greater thickness of lignite seam, thinner overburden, greater height of the lignite horizon above sea level etc.; and it has been estimated, we think reasonably, that the reserve in this area is around 200 million tons. The thickness of the lignite in the selected area is, except at one or two places, over 20 ft. and averages over 50 ft.; and the thickness of the overburden varies from about 160 ft. to 250 ft. The ground surface in this area is 160 feet above the mean sea level and the base of lignite formation 80 feet below it. Drilling of supplementary bore holes, widely distributed over the prospective mining area, has been taken in hand at the instance of Powell Duffryn with the object of checking further the thickness of the lignite seam and proving the ground for about 150 ft. below it. This work, which is, in our view, clearly essential, is at present in progress.

4. Upto date only about 100 tons or so of lignite has been mined from the single shaft and the boreholes mentioned above. The analysis of the mined lignite has shown that it is eminently suitable for production of ammonia synthesis gas. To quote from Chapter IX of the report submitted by the Powell Duffryn Technical Services Ltd., "The Neyveli lignite, by virtue of its low ash and sulphur content and also on account of its high content of volatile matter, is well suited for the production of ammonia synthesis gas." The composition of a representative sample of the raw lignite as mined is reported to be as follows:

Moisture	56 per cent.
Ash	2·5 per cent.
Volatile matter	22·4 per cent.
Fixed carbon	19·1 percent.
Higher and lower calorific values	4,920 and 4,217 B.Th. U/lb

5. While the preliminary conclusions about the extent of the lignite deposit and the quality and characteristics of the lignite are certainly extremely promising, it has to be borne in mind that investigations in these matters are still by no means complete. Full-scale intensive investigations have, indeed, been started only lately and it will be sometime before final results are available. Before it can be said with complete confidence that the mining of Neyveli lignite is feasible, technically and economically, and the cost of winning lignite can be assessed with a fair degree of accuracy, a problem of some magnitude has to be solved. All attention is at present concentrated on the investigation and solution of this problem which centres round the presence of artesian water almost immediately below the lignite bed. There are aquifers above and below the lignite but the bulk of it including artesian water is tapped at less than 20 ft. below the lignite. Powell Duffryn have come to the conclusion that no reliance can be placed on the existence of any impermeable barrier bed under the lignite; consequently if no steps are taken to relieve the artesian pressure, the artesian water would in all likelihood burst into the open cut mine (open cut mine being the only practicable method of mining in view of the soft, friable and light nature of lignite) and would stand 180 ft. above the mine floor, were the water allowed to rise to the level of pressure surface. The water pressure that would be exerted if the lignite is extracted has been estimated to be 8 tons

per sq. ft. A trial mine pit or pilot quarry 600 ft. square is being dug and overburden has been removed to a depth of 140 ft. or so after which all work has been stopped until steps are taken to relieve artesian pressure.

6. Powell Duffryn have come to the conclusion that the only solution of the artesian water problem is to lower the water table below the immediate mine excavation to a depth of 50 ft. below the base of the lignite and to drain the water-logged beds above and below the lignite to this depth. In their view such a local depression in the water table can be effected by means of a grid of boreholes of sufficient depth drilled at appropriate distances apart and equipped with submersible pumps, new boreholes being drilled and the pumps being moved forward progressively with the advance of the mine workings; and the number, depth and spacing of the boreholes and the pump capacities being determined by experiments. In their own words, Powell Duffryn recommend, "massive pumping from a network of large diameter boreholes whose spacing, capacity and power consumption remain to be determined; these well-points would be moved in accordance with the progress of the work." They opine that "considerations of the probable volume of average annual intake over a large area, the known discharge of existing artesian wells from the main aquifer, and the fact that these beds have a finite, though as yet unknown co-efficient of transmissibility, suggest that in a reasonably small operating panel the required depression could be maintained by pumping a quantity of the order of 100,000 tons of water per day at an expenditure of 300 H.P."

7. Although Powell Duffryn believe that the artesian water can be controlled in the manner mentioned above and the mine worked in safety, they have, in our view quite rightly, recommended that further pumping tests should be carried out with a view to test and establish the solution suggested by them. They have recommended "a large scale test over an area of perhaps a quarter square mile"; and for implementing this recommendation tenders were invited in February last for certain pumping installations which would not be complete, we understood, before June 1955 at the earliest.

8. The position thus is that confirmatory data about the extent of lignite reserve and underground conditions have still to be obtained and the suggested solution of the artesian water problem has still to be satisfactorily proved. We have, therefore, to regard all conclusions and estimates in the Powell Duffryn report, particularly cost calculations, as somewhat tentative at this stage and contingent upon the final results of the further experiments and tests that are now being undertaken but would not be complete for some months to come. While we see no reason to doubt that no problem connected with the South Arcot lignite mining, including the water problem, would be found impossible of solution and that successful mining of the lignite would be ultimately achieved, we consider, for the reasons we have indicated above, that it is not possible at this stage to arrive at any completely reliable data for calculating the cost of pumping water or of mining lignite.

9. Subject to the above reservations we note that Powell Duffryn have calculated the cost of mining lignite variously between Rs. 5.4 and Rs. 14.3 per ton according to the method to be used and the quantity of lignite to be mined annually. Similarly, they have

estimated the generation cost of electricity at varying figures between 0.48 anna and 0.79 anna per unit. Were the fuel cost to increase by 50 per cent. or 100 per cent. the power generation cost would increase correspondingly and, according to Powell Duffryn's estimate, amount to, in the first case, between 0.55 anna and 0.96 anna and in the latter case, between 0.61 anna and 1.13 annas.

10. *Palana lignite*—The Palana lignite fields are situated about 12 miles south of Bikaner city and are connected with it by a good road as well as by railway. The total proved deposits covering an area of $3\frac{1}{2}$ miles $\times\frac{3}{4}$ mile are of the order of 15 million tons of which between 2-3 million tons have been extracted since the turn of the century up to date. Recent prospecting has proved another 2 million tons or so and therefore the total unexploited reserves can be taken to be about 15 million tons. Evidence of lignite occurrence has come to notice while sinking wells near Kolayet nearly 20 miles to the west of Palana as well as at certain other places like Khari, Ganga Sarower and Chaneri within a radius of 20 to 30 miles from Palana. This has given rise to the expectation that the lignite fields are probably a good deal more extensive than what is indicated by the proved deposits.

11. The overburden varies from 131 ft. to 305 ft. in depth and the thickness of lignite seam from 3 ft. to 61 ft. The seam has its greatest thickness on the SW border and tapers off gradually towards the NE end. The mining method adopted so far is the "Pillar and Stall" method which is completely unsuitable for winning lignite in view of its physical characteristics, particularly its lightness and friability. In consequence, the average rate of winning is less than 15 per cent of the total seam worked; only in one isolated area, worked between 1950 and 1953, extraction was of the order of nearly 38 per cent while in all other areas the rate of extraction has varied between less than 1 per cent and $22\frac{1}{2}$ per cent. Almost the whole of the proved area has been sporadically exploited in this rather wasteful manner resulting in, as stated above, a total extraction of between 2 and 3 million tons.

12. The only satisfactory method of lignite mining is open cut mining which must be resorted to for full and economic exploitation of the balance of the deposits. On the basis of shaft mining operations, the actual cost of winning a ton of lignite amounts to, we understand, roughly Rs. 12, the selling price at pithead being Rs. 17 per ton. The adoption of open cut mining method will probably increase the cost to some extent, but we can safely assume that it is unlikely to be more than Rs. 15 per ton f.o.r. Palana. The present method of mining by sinking deep shafts involves not merely leaving most of the lignite underground but is expensive as well since close timbering is required for the protection of roofs and walls in the underground galleries and the timber required for the purpose has to be imported from Madhya Pradesh. Open cut mining will do away with timber requirements and if steady extraction of a minimum quantity of about 500 tons per day is achieved, we do not see why the cost of mining per ton should be any more than what we have assumed; it may indeed turn out to be no more than the current cost i.e. Rs. 12 per ton. It is interesting to note that some years ago, the Bikaner State Government decided to introduce open cut mining and actually purchased, on the advice of a Scottish mining engineer, a good deal

of expensive machinery for the purpose. The idea was, however, abandoned shortly afterwards when it became known that Bhakra Nangal Power would be available in Bikaner and render continued local generation of thermal power unnecessary.

13. At the moment only about 2,500 tons of lignite is being mined every month from a single shaft, though in the past the monthly quantity mined has been upto seven or eight thousand tons. The lignite extracted from Palana fields is currently being used in the Bikaner Power House along with Bihar coal in the proportion of 80 per cent lignite and 20 per cent coal. The power plant has an installed capacity of 7,500 K.W. and supplies power to places as far as 150 miles away, the power generation cost being roughly 3 annas per unit.

14. All available literature indicates that Palana lignite is notoriously liable to self-combustion but we found several hundred tons of lignite stacked at the Bikaner Power House and were told that upto date the stacking has created no problem of self-ignition. The *analysis and calorific value of Palana lignite is as follows on an "air dried" basis:

Moisture	26·70 per cent.
Mineral matter	4·84 per cent.
Carben	52·32 per cent.
Hydrogen	4·74 per cent.
Sulphur	1·68 per cent.
Nitrogen	0·91 per cent.
Oxygen (by difference)	8·81 per cent.
Calorific value	9,740 B. Th. U/lb.

15. We consider Palana lignite suitable for gasification and taking roughly a utilisation of 2.75 tons of lignite† per ton of ammonia and assuming a production of 300 tons of ammonia a day, we estimate that the annual requirement of lignite would be around 270,000 tons. Even if the workable deposits are therefore assumed to be of the order of 12 million tons only, they should last nearly 45 years presuming that the deposits will hereafter be carefully reserved for ammonia synthesis and their use for purposes of fuel or power generation will be completely banned.

(2) SPARE AND WASTE GASES

16. *Oil refineries*—The recent establishment of oil refineries at Trombay near Bombay has opened up possibilities of a new and valuable source of synthesis gas. We refer primarily to refinery gas. though a considerable quantity of low grade fuel oil and oil waste might also be available from the refineries. This would be an equally good raw material for manufacture of synthesis gas and it may be possible to secure it at a cheap price since there is little use or demand for it in the country at present. The total quantity of gas which the two refineries will yield is, of course, very large but not all of this would be available for production of synthetic ammonia. The refineries' own requirements of gas are considerable and it would

* F.R.I. analysis. Total moisture of lignite as *mined* is 43.3 per cent.

†As mined, with a moisture content of 43.3 per cent.

also be in the interest of the country that as much gas as may be required should be earmarked for development of petrochemical industries. Even after all this utilisation, however, and after removal of useful hydro-carbons like ethylene for other and better purposes, a fair quantity of gas would still be left over of which the best use that can be made is production of synthetic ammonia. We enclose an analysis of residual gas which we have obtained from one of the two refineries (Annexure V); we estimate on the basis of this analysis that a ton of ammonia can be made for every 16500 cu. ft. of gas.

17. We have learnt with some concern that the management of the smaller of the two refineries—Messrs. Standard Vacuum Oil Company—has contracted to sell to Tatas a part of their fuel production (which may include some refinery gas) for burning in boilers for thermal power generation. Though the transaction may have been a good bargain from the seller's point of view, we suggest that the burning of valuable gas for only heat generation should be deprecated in the national interest. Even after allowing for Stanvac's commitment in this regard, we have been told that 2,300,000 cu. ft. of gas per day (of approximately 2000 B.T.U. per cu. ft.) would be available from Stanvac refineries which, we estimate, is sufficient for a daily production of 140 tons of synthetic ammonia. Despite the enquiries and personal contacts we have made, we regret we have been unable to get an exact idea of the spare gas, if any, likely to be available from Burmah-Shell's refineries. Burmah-Shell's plant is a much larger plant* and as far as we are aware, unlike Stanvac, Burmah-Shell have not entered into any commitment with any party for the disposal of any portion of their gas production. They have, we understand, some idea of making ammonia or even some type of nitrogenous fertiliser either by themselves or in association with indigenous financial and industrial interests. We have, however, reasons to believe that Burmah-Shell's ideas on the subject have not yet taken a definite shape and it is not impossible that they may ultimately be disposed to sell their gas and give up any idea of processing it themselves. Apart, however, from the question of the agency which will utilise the gas, what is certain is that a considerable quantity of gas would be available from the Burmah-Shell refinery for manufacture of synthetic ammonia. We have been reliably given to understand that the available gas would be of the order† of at least 30,000 tons and might indeed be as much as 50,000 tons per year.

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* The proportion is, Burmah-Shell: 40; Stanvac: 25.

† In a letter dated the 16th April 1955, Burmah-Shell have written to us to say that "the best estimate which can be made at present is 50 000 tons per annum maximum of refinery gas which would contain some nitrogen, hydrogen sulphide and hydrogen together with varying quantities of paraffinic and olefinic hydrocarbons containing 1 to 4 carbon atoms, the relative proportions between the individual constituents depending firstly upon the particular type of crude being processed and secondly upon the operating conditions of the catalytic cracking process." Assuming availability of 50,000 tons per year or 4.1 million cu.ft. per day of Burmah-Shell refinery gas, and assuming that its composition will be more or less the same as that of Stanvac gas (since the processes adopted in the two refineries are, it is understood, similar), the total quantity of gas available from the two refineries would be sufficient for a 97,000 tons/year Nitrogen plant.

18. The indications thus are that spare gases from the two Trombay refineries might yield enough ammonia for a total production of at least 70,000 tons of nitrogen a year, probably considerably more. On account of the nature of operations in the refineries, the gas supply is not likely to be continuous throughout the year. We have been told that continuous supply may not be possible for more than 320 days a year. This minor difficulty can however be conveniently overcome if the ammonia synthesis plant is designed to process any hydro-carbon stream such as fuel oil or petroleum crude and not only gas. Indeed, if, as we have surmised, low grade fuel oil can be arranged for at a reasonably cheap price, this would not only help to overcome the handicap of discontinuity of gas supply but also (i) permit installation of a larger plant; and (ii) possibly improve the economics of the project.

19. An important question that will have to be tackled, assuming availability of refinery gases for ammonia synthesis, is the fixation of a fair price for this raw material. It has been suggested in certain quarters that the price of spare gas should be the same as the current price of fuel oil on a comparative heat value basis. The main argument urged in support of this suggestion is that refinery gas can, for any purpose, be used as a substitute for fuel oil and if that is done the fuel oil thus saved can be sold and will fetch its proper market value. We are, frankly, not impressed by this argument and we are definitely of the view that the price basis suggested would be unfair to the buyer. Due account should, we feel, be taken of the fact that the demand for fuel oil in the country is limited, and that it will be difficult, if not impossible, to find indigenous market for the entire output of fuel oil from the refineries at anywhere near the present price-level. We consider, on the whole, that the *highest price* which the seller can legitimately expect for the gas is equivalent cost* of coal transported to Bombay from the nearest coal fields on a comparable heat value basis.

20. *Coke oven gas*—We suggest that as a matter of general policy, India should in future follow, wherever feasible, the recent American practice of associating ammonia synthesis plants with large steel works such as those which have been approved for installation at Rourkela in Orissa and in the Bhilai Region in Madhya Pradesh. A sufficient reason for such integration is the fact that capital investments and production costs are low when ammonia is made from coke oven gas. In this sense, coke oven gas is the cheapest raw material for ammonia synthesis after catalytic reformer gas. We refer in this connection to an interesting article† under the caption "Economics of ammonia manufacture from several raw materials" in January 1955 issue of "Chemical Engineering Progress". The article satisfactorily establishes that capital investment in an ammonia plant based on coke oven gas is lower than that in a plant based on natural gas or fuel oil or coal;‡ and so are production costs.

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* On this basis, the price of gas will amount to, roughly, 25 annas per million B.T.U.; while on the basis of the current fuel oil price (Rs. 102 per ton), it will amount to about 40 annas per million B.T.U.

† For our acquaintance with this article and for access to much of the information and material in this and the two following paragraphs we are indebted to Dr. M. S. Patel of Santa Cruz, Bombay.

‡ Investment and production costs increase in the order in which the three raw materials are mentioned.

21. It is possible, of course, for a steel plant to utilise in some way or other all the available blast furnace and coke oven gas; but this arangement, we are convinced, is not the best that can be made: the arrangement is, in any case, not in the interest of all-round economy. Even from the point of view of satisfactory steel production alone, no inconvenience would result if the coke oven gas is at least stripped of its hydrogen content (49 per cent to 51 per cent of total gas) and the heat potential thus lost is made up by the utilisation of extra fuel oil/tar/coal. A steel plant will in all probability have much to gain if it allows removal of hydrogen from coke oven gas and takes back the hydrogen-free gas for steel making purposes, because in that event:

(i) it will not have to instal a sulphur removal plant;

(ii) it will not require a sulphuric acid plant;

(iii) it will get a richer gas than the whole coke oven gas; the richer gas would give a more luminous flame in the open hearth furnaces;

(iv) it will not require an oxygen production plant because in securing its nitrogen requirements the associated synthetic ammonia plant will obtain oxygen as a by-product and will thus be in a position to supply as much oxygen as the steel plant may need; and

(v) if low grade fuel oil is used as a substitute for hydrogen and can be had cheaply, the substitution may result in some saving for the steel plant.

22. The advantages enumerated above represent only one aspect of total economy; for on the fertiliser production side there is the advantage of lower plant costs and consequently lower costs of production. It is quite possible of course to utilise the total coke oven gas for ammonia synthesis by combining fractionation with cracking and/or partial oxidation, but such utilisation of total gas will involve more extensive use of alternative fuels in the integrated steel plant and this may not always be convenient. Even on the basis of hydrogen removal, however, economic ammonia production units can be set up in association with the new steel projects. With the Rourkela plant, for example, which according to the latest decision, will have a turnover of a million tons of ingot steel per year, and consequently a throughput of about 4,000 tons of coal a day in its coke oven batteries, can be easily associated an ammonia synthesis plant with a designed production capacity of at least 250 tons per day.

23. We hope that the suggestion we have made above will carry weight with the authorities who may be concerned with the setting up of future steel plants. We note that the German collaborators of the Rourkela plant, Messrs. Krupp Demag, have designed it on the basis of utilisation, in the Steel Works themselves, of the entire quantity of all available blast furnace gas and coke oven gas. We have seen a letter from them dated the 14th December 1954 in which they have clarified that "all blast furnace coke (?) and coke oven gas will absolutely be necessary for the production of steel and its further process of manufacture. There is no possibility in the first stage to supply blast furnace gas or coke oven gas to a fertiliser factory or cement factory to be erected in connection with the Steel

Plant at Rourkela". We have had informal enquiries made from them as to whether they would be prepared to make the necessary adjustments and changes in design so as to permit removal of hydrogen from coke oven gas, and the advantages attendant on this arrangement have been brought to their notice. Up to the time of writing this report, however, we have had no indication that they might be prepared to change their previously expressed views.

(3) GYPSUM

24. The authorities of the Geological Survey of India have referred us, for latest information on Indian gypsum, to an article by two officers of the organisation, Messrs. D. R. S. Mehta and V. P. Sondhi, entitled "Gypsum in Indian Union." The publication is a valuable compendium of currently available information* on gypsum occurrences in India and we have, therefore, incorporated it as an appendix to our report (Appendix IV). It shows that the main gypsum deposits in India which can be regarded as suitable for commercial exploitation are in (1) Rajasthan; (2) Saurashtra-Kutch; and (3) the district of Trichinopoly in Madras State. We have visited parts of all these three reserves and we summarise briefly below the conclusions we have reached about the extent of each reserve and generally its potentialities for purposes of fertiliser production.

25. *Rajasthan*—The Rajasthan reserves occur mainly in the two States of Bikaner and Jodhpur and the best known and probably the most valuable deposits are at Jamsar about 20 miles† north of Bikaner city. The mines are within a stone's throw of Jamsar railway station on the metre gauge railway connecting Bikaner to the south with Bhatinda to the north *via* Hanumangarh. The Jamsar deposits have all along been worked by a private concern, Messrs. Bikaner Gypsums Ltd., under a lease granted by the late Bikaner Government and the mining area covers roughly about 2 sq. miles. Our conclusion, on local investigation, was that the minimum deposits in the Jamsar area can, in the light of the latest available data, be computed to be of the order of 30 million tons of good quality gypsum of well over 80 per cent purity. In the Jamsar mines gypsum occurs almost invariably in three seams or sections placed horizontally one above the other. The top seam lies under a thin overburden of sand and consists of amorphous gypsum of 72 to 88 per cent purity, average purity being around 85 per cent calcium sulphate ($CaSO_4$ $2H_2O$). The amorphous gypsum is underlain by a crystalline seam below which, separated by a 8 to 10 ft. thick layer of sand, there is a third layer of much harder rock-like gypsum. The crystalline variety is 88 per cent to 95 per cent calcium sulphate and the bottom layer of rock gypsum is purer still. Roughly it can be said that in a section of 60 ft. deep, 40 ft. is gypsum of one variety or another and the rest overburden or intervening layers of sand and sandy clay.

26. Exploration and proving of gypsum deposits in the Rajasthan desert are by no means complete yet. Apart from Jamsar which is the richest reserve known so far, and which is being explored and

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*The information is not, however, entirely uptodate in every respect.

†There is a 22 miles long Kutcha road or desert track connecting Bikaner with Jamsar. The road is motorable or at least "jeepable" nearly throughout the year.

mined by a private company, systematic commercial proving is being done by the Sindri Gypsum Development Officer who has his headquarters at Jodhpur and has modern machinery and equipment and trained personnel at his disposal. Up to date, nearly 230 separate deposits (situated within a distance of 10 to 40 miles of existing railway lines) have been explored and on the basis of the results of these explorations, it can be safely estimated that the total quantity of proved gypsum in Jodhpur and Bikaner, inclusive of Jamsar, is around 125 million tons. Of this at least 40 million tons have a minimum purity of 85 per cent and another 20 million tons are between 80 and 85 per cent pure calcium sulphate. The Sindri plant has been built to process gypsum with a minimum purity of 85 per cent, but the *average* purity required by Sindri, having regard to its limitations regarding filtration capacity etc. is 87 per cent. We would suggest for consideration that should a new ammonium sulphate/sulphate-nitrate factory be built on the basis of utilisation of Rajasthan gypsum, it should be designed to process gypsum with an average purity of 82 per cent and a minimum purity of 80 per cent so that the considerable reserve of medium grade gypsum of 80 to 85 per cent purity can be satisfactorily utilised.

27. If our estimates are in excess of those furnished in the report of Messrs Mehta and Sondhi it is because we have had the advantage of seeing the results of later explorations and provings. On the basis of latest available information, we regard indeed our own estimates to be on the conservative side and are confident that further proving and exploration will establish that the extent of reserves is even larger. Taking into account Rajasthan gypsum alone, we consider it, on the whole, safe to suggest that there is room for establishing another factory using the same quantity of sulphur radical as Sindri (but not probably more than one more) on the basis of its utilisation provided, as suggested above, the plant is designed to process gypsum of a minimum purity of 80 per cent and an average purity of 82 per cent. The processing of medium grade gypsum will naturally involve higher plant costs, lower production per ton of gypsum, and therefore higher costs of production but, we have been assured, no technical difficulty. Higher production costs should however, to some extent, be offset by lower price* for medium grade gypsum.

28. *Saurashtra-Kutch gypsum*—The most important occurrences in Saurashtra lie in Halar district between the Jamnagar-Dwarka section of the Saurashtra railway to the South and the gulf of Kutch to the North and cover an area of roughly 15 to 18 sq. miles. Gypsum along with bauxite occurs where a narrow strip of Gaj limestone lies wedged in between the Deccan trap of eastern Saurashtra and the laterite belt to the extreme west. As noted in the report of Messrs D. R. S. Mehta and V. P. Sondhi, the principal occurrences are in three villages Bhatia (which is a railway station on the Jamnagar-Dwarka Section of Saurashtra railway), Ran and Virpur. Virpur is on the gulf coast and Ran is in between Virpur and Bhatia. Gypsum mined in this area can thus be transported to Sikka port either by rail *via* Bhatia railway station or by sea from a very minor and probably unrecognised but quite convenient "port" at Pindara

* Because it is easy to mine, even high grade Rajasthan gypsum is relatively cheap. For 87 per cent pure gypsum Sindri has never paid a pithead price of more than Rs. 7 per ton.

near Virpur. We understood from local enquiry that sea freight from Virpur to Sikka is Rs. 3/14/- per ton while the railway freight from Bhatia to Sikka is 3/8/- per ton.

29. In the report of the Geological Survey of India gypsum reserves in this area are estimated as below:—

Ran	...	...	...	...	3,776,000 tons
Bhatia	...	...	...	...	175,000 tons
Virpur	...	...	...	...	490,000 tons

Actually, however, no systematic proving has been done at any place except at Ran. In the Ran area systematic exploration by sinking boreholes was done in 1948-1949 by the Geological Survey of India and the estimate of 3¾ million tons can be accepted as fairly conclusive. In regard to the other two villages Bhatia and Virpur, the estimates are a matter of rough guess and are, perhaps rightly, extremely conservative: and all that can be said with confidence is that the reserves at Bhatia and Virpur are *at least* as much as what has been conservatively estimated by Geological Survey. At Virpur intensive investigations are now being done by the State Government and during our visit we understood that below a four feet thick overburden the selenitic clay bed goes down to a depth of between 30* ft. and 56 ft. On the whole, we are inclined to think that on further proving and exploration the estimated reserve of Saurashtra gypsum in Halar district will merit revision in an upward direction. On the basis of the investigations done recently by the State Government, they have provisionally concluded (and the conclusion appears to us to be reasonable enough) that the Virpur reserve is of the order of 2 million tons against the G.S.I.'s estimate of half a million ton.

30. In the entire area gypsum occurs in the form of selenitic veins and segregations mixed with clay. The experimental pits sunk at Virpur indicate the presence of a ton of selenitic gypsum per 600 cu. ft. of clay and marl while at Ran it is reported to be a ton per 500 cu. ft. It would be safe to conclude on the whole that in the Halar area gypsum forms between 3 and 5 per cent of the clay bed where it occurs.

31. At the moment no mining at all is being done in the richest deposits at Ran, probably because it is farther away from the railway line than Bhatia and from the gulf coast than Virpur. At least two of the three cement factories in Saurashtra (that is, those at Dwarka and Sikka but probably not the one at Porbander) obtain their gypsum supplies from the Halar area; and the Associated Cement Company who own the Dwarka factory have made their arrangements through local contractors who, we understood, charge Rs. 19† per ton of gypsum loaded in wagons at Bhatia railway station. The current mining methods are uneconomic and also wasteful. If underground water is met in any quantity or a more than one foot thick layer of limestone has to be tackled, the pits are left unexploited, and mining is shifted to a virgin patch.

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* Compare this with the estimated thickness of 11 ft. 6 inches as per G.S.I.'s reports.

† The cost of qurrying at present in said to be around Rs. 15 per ton.

32. It is, we understand, possible to work the Saurashtra gypsum mines economically by one or other or a combination of the following methods:

(1) Ground sluicing or ground shearing;
(2) Hydraulicing; and
(3) Dredging.

We understood that these mining methods are about to be tried by the State Government at Virpur on an experimental scale and in the light of the results of this experiment the method which proves to be most economical and suitable will be selected. The adoption of modern mining methods will probably satisfactorily overcome the two chief difficulties which are now encountered namely, (i) presence of surface limestone and (ii) presence of underground water which is met at a depth of 20 to 25 ft. at Ran and Bhatia and at a depth of 10 to 15 ft. at Virpur. On the other hand, occurrence of plastic clay may present a difficulty not too easy to overcome. Saurashtra Government have estimated, on the basis of adoption of modern mining methods, that the cost of winning gypsum should be no more than about Rs. 12 per ton and it would be possible, after paying sea or railway freight, to deliver the gypsum at Sikka at Rs. 16 per ton. We are a little doubtful about this assumption; while we agree that the adoption of modern mining methods is absolutely essential for maximum exploitation of the reserves, we hardly think that it will bring about any significant reduction in mining costs.

33. Because of the selenitic nature of the gypsum it is easy to separate it from adhering clay and other impurities and, when cleaned, the gypsum is exceptionally pure, there being very little ingrained clay or dirt. We had a representative sample analysed by the Gypsum Development Officer of Sindri who has reported the following results:

$CaSO_4\ 2H_2O$	97.88%
Silica	1.47%
*NaCl	0.0185%

34. The deposits in Kutch (which we have not seen) are reported to be more or less of the same quality as Saurashtra gypsum and the occurrences are said to be similar in nature. The currently accepted estimate of total reserve is just over 2 million tons. The average quantity of gypsum per 1000 cu. ft. of clay is reported to vary between half a ton and nearly 2½ tons.

35. Even the current estimates of the total reserve in Saurashtra and Kutch are not too small to be ignored and the indications are that further investigations and systematic proving will justify their upward revision. Further, the gypsum is high grade selenite with a minimum purity of 96 per cent though in view of the nature of its occurrence it is more expensive to win than Rajasthan gypsum. Apart

* The NaCl content is relatively high and is on the border-line of what is normally deemed permissible in gypsum meant to be processed for the manufacture of ammonium sulphate. Chiefly for this reason we have requested the Sindri management to process Saurashtra gypsum in bulk and report the results to Government. We suggest also that further samples of Saurashtra gypsum, selected at random, should be analysed to find out, in particular, their incidence of NaCl content.

from whether or not a factory is located now or in future at Sikka or elsewhere in Saurashtra, we consider that suitable scope should be found for the proper utilisation of these valuable deposits and also that early steps should be taken to prove them fully.

36. *Trichinopoly*—We enclose in Appendix IV a monograph by Dr. M. S. Krishnan under the title "Mineral Reserves of Madras" published in Vol. 80 of the Memoirs of the Geological Survey of India. This monograph and the article by Messrs Mehta and Sondhi adequately furnish between them available information with regard to the nature of gypsum occurrences in Trichinopoly district, the area where the gypsum occurs and its quality, the probable extent of the reserves and the attendant mining problems. We propose to supplement the information given in these two documents by a brief record of our personal observations and impressions.

37. The area of occurrence is roughly 22½ sq. miles and the currently accepted estimate of total reserve is 15,300,000 tons. The nature of occurrence of Trichinopoly gypsum is very similar to that of Saurashtra gypsum except of course that Saurashtra gypsum is selenitic and is a good deal purer than the fibrous gypsum in Trichinopoly deposits; on the other hand, the mining problems in Saurashtra quarries connected with the presence of underground water relatively near the surface or intervening thick layers of limestone do not exist in Trichinopoly.

38. The area of gypsum occurrence covers a number of villages and is all waste land, portions of which have been leased out by the State Government to various parties on the basis of payment of a dead rent/royalty. Either dead rent at the rate of Rs. 10 per acre per year or royalty is payable, whichever is greater. Royalty is calculated at the rate of 5 per cent of pit-head price (that is, the cost of mining) and comes to, we understood, 10 annas per ton of gypsum recovered. Compensation for spoiling the land is also payable, after operations are over, at the rate of Rs. 10 per acre. In addition, cess is levied at 5 annas per rupee of royalty.

39. We understood that Fertilizers and Chemicals Ltd. of Travancore have taken a lease of about 500 acres. A private company, Trichinopoly Mining Works Limited, have taken another 3,500 acres on lease. Both employ contractors who charge Rs. 12 per ton of gypsum recovered. After recovery, which is done by the primitive method of digging with pick axes and shovels, gypsum is allowed to dry when much of the adhering material* falls off; thereafter it is scraped on the mine site. The roughly cleaned gypsum is then transported by hired lorries to Ariyalur, which is the nearest rail head, the transportation costs working out to about 3 annas per ton mile. The main mines are located at the village of Odiyam, 13 miles from Ariyalur. Transportation costs, inclusive of loading at Odiyam and unloading at Ariyalur railway station, thus come to a little over Rs. 6 per ton. There are arrangements for washing the gypsum at Ariyalur but these arrangements again are of a make-shift type and

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* The adhering material is largely chalky clay most of which falls off upon drying and washing but some of the dirt and clay is so ingrained that it can never be completely washed off. No amount of treatment can thus bring the Trichinopoly gypsum to the high standard of purity of Saurashtra selenite.

also wasteful. A concrete mixer is used for washing purposes and it is only after washing that gypsum acquires a standard of 80 to 85 per cent purity. The washing costs Re. 1 per ton and re-loading into railway wagons at Ariyalur another 8 annas per ton. By the time the gypsum reaches Alwaye factory *via* Cochin Harbour Terminus, the total cost comes to over Rs. 43 per ton inclusive of about Rs. 13/8/- on account of railway freight from Ariyalur to Cochin Harbour Terminus and Rs. 7/12/- on account of transportation (including handling) from the Terminus to the factory. After the gypsum is received in the factory it is used directly in the process after drying and pulverising. The Alwaye factory does not entirely depend upon Trichy gypsum; it imports a part of its requirement from Cyprus which is much purer gypsum and does not require drying and has better yield in terms of the end-product, ammonium sulphate.

40. Our enquiries have led us to conclude that the Trichinopoly gypsum is quite suitable by itself, that is, without admixture with imported or high grade gypsum, for processing for manufacture of ammonium sulphate and the average purity that can be depended on, even without meticulous beneficiation, is between 80 and 85 per cent. We estimate that the cost of gypsum cleaned and washed according to the methods now employed does not exceed Rs. 22 or Rs. 23 per ton f.o.r. Ariyalur. Trichinopoly Mining Works Ltd. supply gypsum to cement factories at Rs. 25/8/- per ton f.o.r. Ariyalur.

41. The mining methods employed at present are definitely wasteful; all over the area where gypsum occurs, "plums" are literally being taken out of the "cake". We were not impressed by the opinion locally held that mechanisation of mining operations is not a feasible proposition or that the cost of introducing mechanisation would be prohibitive. Even though mechanisation may not bring about any reduction in the cost of winning and might possibly actually enhance it, the adoption of modern mining methods is absolutely essential for maximum possible exploitation of these valuable gypsum reserves down to a depth of 50 ft. which is hardly ever reached by contractors employing local labour. On our request Shri H. N. Ganguli of Bikaner Gypsums Ltd. has been good enough to go into this question in some detail as well as into the question of beneficiating Trichinopoly gypsum with a view to improve its purity beyond 85 per cent. He has given us a very interesting report which we reproduce in Appendix IV. We would refer, in particular, to his opinion that by the adoption of suitable beneficiation technique a purity range of 85 to 90 per cent can be easily maintained and also that the minimum exploitable reserve is at least of the order of 30 million tons and might be considerably larger. We draw attention also to his view that even after introduction of up-to-date methods of beneficiation and mechanised mining, the cost of gypsum delivered at Neyveli would not exceed that of Rajasthan gypsum delivered at Sindri. These views are naturally tentative, but coming as they do from a practical and successful mining engineer of Mr. Ganguli's experience and reputation, they are, we suggest, weighty enough to deserve careful checking up by the authorities of the Geological Survey of India. Should his conclusions be confirmed even partially, they would justify dependence on the Trichinopoly deposits for supply of the required sulphur radical for a large factory consuming as much gypsum as Sindri. Even on the basis of the estimates of

reserves officially accepted at present, it would be justifiable to locate an ammonium sulphate/double salt factory in the neighbourhood consuming half as much sulphur radical as Sindri.

(4) SULPHUR AND PYRITES

42. *Son Valley pyrites deposits in the district of Shahabad in Bihar*—The best known outcrop and the one which alone has been worked to a very limited extent is at Amjor about 3 miles north of Banjari railway station on the narrow gauge railway line connecting Dehri-on-Son with Rohtas alongside the left bank of the Son. There is a kutcha road connecting Banjari with the hill face where a pyritic outcrop has been worked jointly by the Kuchwar Lime & Stone Co. Ltd. and the Geological Survey of India. Pyritic outcrops have in fact been noticed at least at seven different places widely separated from each other and some of them were discovered as late as 1952. The known occurrences are on practically all sides of two distinct plateaux divided only by a narrow gorge and the visible outcrops are on perpendicular hill scarps from which vegetation and debris have been washed away by rain water. The distance between the outermost outcrops, either North-South-wise or East-West-wise, is between 7 and 8 miles. The entire area is wild and mountainous, mostly covered by thick forests and flat-topped hill ranges intersected by deep ravines. The particular locality where the Amjor deposits have been discovered used to be the zamindary of Messrs. Kuchwar Lime & Stone Company, but along with other zamindaries in Bihar the property has recently (only in December last) been taken over by the State Government and therefore now vests in the Government of Bihar except an area of 5½ acres or so where the Kuchwar Lime & Stone Company have done extensive prospecting and a limited amount of mining as well. Although three adits were drilled through the hill face at Amjor partly by the Kuchwar Lime & Stone Company and partly by the Geological Survey of India, all mining work seems to have been abandoned for some time now. On enquiry we understood that the working of the mines has been stopped because there is at present no demand for iron pyrites in the market. We were told by the representatives of Kuchwar Lime & Stone Company during our local visit that when the deposits were being exploited on a small scale, the cost of mining raw pyrites was around Rs. 20 per ton.

43. We have carefully studied all available literature on the nature of pyrite occurrences in this area and have selected for incorporation in this report the following three documents which we think are valuable (Appendix V).

(i) An article published by Mr. D. Kerr-Cross of the Geological Survey of India in April 1952 issue of "Indian Minerals" under the title "Some notes on the underground exploration of the Amjor pyrites deposit and the system of roof bolting used there."

(ii) A note by Mr. J. B. Auden dated the 25th February 1953 on the exploratory mining work undertaken by the Geological Survey of India at the Amjor pyrite deposits; and

(iii) A note dated December 1953 on the pyrite deposits of Shahabad district in Bihar by Mr. Mukti Nath, Geologist, Geological Survey of India.

The publication mentioned last is particularly valuable since it summarises the results of all previous investigations and contributes a fair amount of new knowledge on the subject. It seems that with a grant of Rs. 75,000 sanctioned by Government in 1951 fresh exploratory work was undertaken by the Geological Survey of India in the autumn of that year and continued up to the end of 1952. When the grant was exhausted, the local organisation was wound up in December 1952 since when no further investigations have been made.

44. The quality of Amjor pyrites is reported to be good and to compare favourably with that of good quality Spanish and Cyprus pyrites, though unlike them it does not contain any copper or other valuable mineral. In terms of sulphur content, however, and therefore as a potential source of sulphur, the Amjor pyrite is in no way worse than almost any pyritic occurrence in any other country.

45. There are unfortunately no conclusive data about the more important question of the probable extent of the deposits. We were driven to the conclusion, at the end of our investigations, that although the occurrences have been known for a very long time, at any rate since 1938, sufficient exploratory work has not yet been done to justify any positive finding on the question of reserves. The estimates which we have seen vary, to a bewildering extent, between 50,000 tons and 50 to 75 million tons. The reasons for these widely differing estimates have been explained in Mr. J. B. Auden's note of the 25th February 1953. We have no doubt that the recent exploratory work done in 1952 has dispelled any notion that the occurrences are lenticular in nature and may not be much in excess of 50,000 tons or so. It has established that the pyritic bed is at least continuous within the area covered by the triangle formed by the three boreholes put down by Kuchwar Lime & Stone Co., one near the Amjor outcrop through which adits have been drilled, another about 1100 ft. to the south of the first one and the third about 2,050 ft. to the south west of the first one. While it is naturally impossible to be certain that the deposits are any more extensive, we would draw attention to the following facts which *prima facie* go to show that even the most liberal estimate of the reserves made so far may not turn out to be an over-estimate at all.

(i) Firstly, the 3 adits which have been drilled on the hill face at Amjor by Kuchwar Lime and Stone Co. and Geological Survey of India and taken to a distance of about 300 ft. or so do not indicate any sign of the three feet pyrite seam diminishing or flattening out.

(ii) Secondly, the three boreholes put down by Kuchwar Lime and Stone Co. at some distance from each other all indicate a pyrite seam of 2 ft. 9 in. to 3 ft. thick *at approximately analogous levels.* The levels do differ to a minor extent but as surmised by Mr. Mukti Nath this may be due to "faulting or folding in the rock."

(iii) Thirdly, pyrite outcrops have been discovered at several other places not only in the neighbourhood of Amjor but several miles away from it e.g. on the Rohtas hill scarps *at approximately equivalent positions.*

It would not, we think, be unreasonable to conclude from these facts at least a strong probability that one continuous bed of pyrites extends throughout the whole region. Should this surmise (though

by no means a wild one, the deduction must after all be regarded as a surmise) turn out to be even partially correct as a result of further exploration, the most liberal estimate that has so far been made of the reserves would be more than justified.

46. On the basis, however, of the little exploratory work that has been done so far, all that we can say with confidence is that the Amjor deposits are definitely measurable at least in terms of several lakhs of tons. The indications are so promising that there is every justification for further exploratory work which may, in turn, establish conclusively that the total deposits deserve to be measured in terms of millions of tons. We agree on the whole with the conclusion which Mr. J. B. Auden has noted at the end of his note that "it is a waste of time to continue to speculate deductively: the only way is to prove the extent of continuity by actual exploration." Apart from its utility as a source of raw material for the manufacture of ammonium sulphate, the Amjor pyrites should be of great interest to this country which lacks any natural sulphur deposits at all. We endorse in the circumstances the latest conclusion of Geological Survey of India in Mr. Mukti Nath's report: "The deposits appear to be sedimentary in nature and are likely to be extensive but in order to be certain about the large reserves of pyrites it is absolutely necessary to prove the deposits by putting bore-holes. preferably angle holes along the escarpment between Amjor and Ghogha and between Bhukhi and Kaula deposits.......... If the bore-holes reveal the extensive nature of the deposit, a few bore-holes may be tried from the top of the plateau to ascertain the extent of pyrites."

47. While we strongly recommend that the above suggestion should be promptly carried out in order that reliable data can be made available as early as possible about the extent of these deposits, we are unable to suggest that the deposits can, in the present state of our knowledge of them, be safely assumed to be a source of supply of sulphur radical for a new ammonium sulphate/double salt factory.

(5) IMPORTS OF SULPHUR RADICALS

48. Besides the somewhat problematical deposits in Shahabad district in Bihar, there is no other known occurrence of pyrites of any significance in India nor there are known occurrences of natural sulphur. In view of this, we have anxiously debated the question whether for making ammonium sulphate/double salt in the new fertiliser production units we should entirely depend upon our resources of indigenous gypsum or visualise utilisation of an imported sulphur radical also; and, in case the latter plan is preferred, the further question as to the types of sulphur-containing materials that can be most advantageously imported.

49. There is no doubt that the best policy is to rely upon indigenous raw materials wherever this is possible. We have come to the conclusion that we can, in the light of our knowledge of the proved gypsum deposits in the country, *safely* base on Rajasthan* gypsum one more but not more than one more factory of the size of Sindri, and further that it would be equally safe to depend on the Trichinopoly reserves (assuming, of course, their proper develop-

* There are location like Bombay and Itarsi, where it is possible to utilise both Rajasthan and Saurashtra gypsum without any disproportionate increase in operational costs.

ment) for operating a near-by factory consuming half as much sulphate radical as Sindri. Taking these facts into account and the further fact that the maximum quantity of *extra* gypsum that may have to be taken into use on the basis of our recommendations would be less than what is being processed today at Sindri and would indeed be only two-thirds of what would be required for Sindri after the implementation of the Sindri expansion scheme, we have come to the conclusion that little or no utilisation of any imported sulphur radical need be contemplated in connection with the current extension programme. In reaching this conclusion we have been guided both by reasons of expediency as well as by economic considerations. We have taken into account the fact that the price of sulphur, and to a lesser extent, of pyrites is subject to wide fluctuations; that ocean freights are rising; that from time to time there has in the past been acute world shortage of sulphur and for some years, particularly after the last war, imports of sulphur from abroad were just unobtainable or could be secured only at an unconscionably high price. If only for these reasons we would advise against installation of any plant designed to process exclusively imported sulphur despite the fact that ammonium sulphate or double salt made by the sulphuric acid process from imported sulphur (at the current price* of Rs. 225 per ton) would be a cheaper product than ammonium sulphate/sulphate nitrate made by the gypsum process—not, of course, at *any* location but only at certain locations conveniently near sea ports and at the same time far away from indigenous gypsum reserves such as Vijayawada, Kothagudiam, Bombay and Durgapur. We have taken into account the fact that the world production of pyrites being more abundant, this commodity is less likely to be in short supply; on the basis of the current price* of pyrites which, according to our information, is around Rs. 125 per ton, we have, however, roughly estimated that compared with the cost of making ammonium sulphate/double salt by the gypsum process from indigenous gypsum, ammonium sulphate/double salt based on imported pyrites would be actually more expensive at Kothagudium and Bombay, almost just as expensive at Vijayawada and only slightly less expensive at Durgapur. We have, again, considered the expediency of installing, at the locations mentioned above, plants designed to process either sulphur, so long as sulphur is obtainable at a reasonable price, or pyrites when sulphur imports become difficult or too expensive; but have not found its economies attractive enough having regard to the heavier capital investment that the arrangement will involve and its ultimate reliance on pyrites.

50. Our final conclusion thus is that all new fertiliser units to be set up under the present expansion scheme should be designed to process indigenous gypsum to the extent that the use of a sulphur radical may be necessary for making ammonium sulphate/sulphate-nitrate. We have indicated at the end of Chapter IV the particular reserves which we think can be most conveniently drawn on for operating the new factories according to their location. We would add, however, that we do not altogether rule out utilisation of imported gypsum as distinguished from imported pyrites or sulphur if (but only so long as) economic considerations or considerations of practical convenience favour this course. While a plant designed to

* Delivered at India Port.

process sulphur or pyrites will be entirely dependent on an imported raw* material, whatever may be its world price from time to time, a plant built to process imported gypsum can always be operated on indigenous gypsum should gypsum imports ever be difficult or impossible at any time on account of an international emergency or should the price of the imported material be artificially raised to an extent to render its continued use uneconomic. We suggest accordingly that there should be no objection to the use of imported high grade gypsum whenever and wherever this may be found to be expedient and economic. It may, for example, be necessary to supplement, for a factory built in South India, the current mining capacity of the Trichinopoly reserves temporarily by import of gypsum from abroad till that capacity can be stepped up to the required extent by the introduction of modern and scientific mining methods which must inevitably be a somewhat slow process.

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* Unless it is a plant designed to process pyrites *and* the economic exploitation of the pyrite deposits in the Son Valley in Shahabad district proves to be feasible at some time in future.

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CHAPTER IV—REVIEW OF STATE GOVERNMENTS' PROPOSALS

In para 18, Chapter II, we recorded the conclusion that in achieving the production target of 100,000 tons of nitrogen a year set before us we should aim to meet the demand in the States and regions in Central, Western and Southern India (comprised roughly in Zones II and III B) and that we should, in the light of the Agriculture Ministry's advice, establish a yearly production of (a) 65,000 tons of urea and (b) 275,000 tons of double salt or, alternatively, an equivalent quantity of ammonium sulphate in terms of nitrogen. Our next task is to recommend suitable locations of the required production units and their capacity. We have taken the view* that in doing so we should have as our main objective the achievement of maximum overall economy, in other words, that we should so plan our production arrangements as to be able to deliver nitrogen at the cheapest possible cost to consumer points.† We have explained that the achievement of maximum overall economy which we have set as our main goal involves the consideration of two independent factors which we may well describe as (a) production economies and (b) distribution economies. In selecting not only locations but also sizes of the new plants and the products to be established there, it is obviously necessary to consider simultaneously both these factors and balance one against the other.

2. We propose to investigate, to start with, the factor of production economies and as the first step in this investigation we discuss in this chapter the advantages and disadvantages of the locations suggested by different State Governments assuming for this purpose utilisation of the raw materials which we have selected as suitable in Chapter III. We have conducted our examination of the State Governments' proposals solely from the angle of production economies leaving out of consideration, for the time being, the factor of distribution‡ costs. We have not thus taken the view that because the new production has to meet largely the demands of Zones II and IIIB, the new production units have necessarily to be located somewhere in the areas which they cover or that a location anywhere else has to be, *ipso facto*, ruled out. It is, we think, quite conceivable that a location elsewhere in India, say in Zone I or Zone IIIA, may have such natural advantages for economic production of the specified fertilizers that overall economy would result by establishing the entire new production there even after adjusting the freight charges that would have to be paid for reaching the end-products to consumer points in Zones II and IIIB.

3. The following is our appreciation of the State Governments' proposals.

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* Para 7, chapter II.

† Other factors we have taken into account in making our final recommendations are (i) transportation facilities, particularly, physical difficulties in the movement of raw materials and end products; and (ii) the size of capital outlay required. We have considered it beyond our province to take into account any other consideration as, for example, need for development of backward areas or for dispersal of State-owned industrial units, etc.

‡ The factor of distribution costs has of course, been very fully taken into account in the final determination of locations—see Chapter V *post.*

(i) TRAVANCORE-COCHIN

In the communication we have received from the State Government it has been explained that while the State "has no proposal for the starting of a new undertaking to produce fertilizers", it is "vitally interested in a proposal for the expansion of the existing capacity of the Fertilisers and Chemicals (Travancore) Ltd. plant at Alwaye". We understand that the proposal adverted to by the State Government was remitted, under the orders of the Government, to a Committee of three whose report, submitted in August last year, is still under consideration.

We have read this Committee's report and we observe that the Committee considered various alternative ways of manufacturing ammonia at Alwaye (i) by burning wood (as at present); (ii) by burning coke/coal; (iii) by burning lignite; (iv) by electrolysis of water and liquefaction of air, and came to the conclusion that the best economies can be secured by adopting the last mentioned process (iv). The Committee concluded that the limit of production on the basis of adoption of the electrolytic process is set by availability of power which is of the order of 50,000 K.W. and is enough to produce only 71.2 tons of ammonia per day. We note that the Committee has calculated that on the basis of a total production of 71.2 tons of ammonia per day by the electrolytic process the cost of production per ton of ammonia would come down from the present figure of over Rs. 700 to Rs. 531 or excluding the element of amortization of existing plant and machinery, to Rs. 471. We note that even this reduced cost will compare unfavourably with Sindri's production cost of Rs. 346 per ton of ammonia.

Since on the substitution of the electrolytic process for the existing process based on gasification of wood, carbon dioxide will no longer be available, the Committee has recommended the establishment of the following production facilities at Alwaye in future:

(i)	ammonium phosphate	50 tons per day
(ii)	ammonium chloride and for utilising the balance of ammonia left over ...	25 tons per day
(iii)	ammonium sulphate based on the sulphuric acid process, elemental sulphur being imported from abroad for the purpose.	

While the proposals formulated by the Committee and the general plan recommended by them represent, in our view, the most feasible way of converting what is now obviously an uneconomic production unit to a reasonably competitive unit, within strict limits and purely for local consuming centres, the conclusion is unavoidable that in the absence of any natural advantages, particularly in the matter of nearness to sources of raw materials, Alwaye is not a suitable location for the establishment of a new fertilizer unit for large scale production of any type of nitrogenous fertilzer; nor is there any room for any further economic expansion of the present production capacity of the existing factory beyond what has already been suggested by the Committee.

(ii) MYSORE

There is a small plant at Belagula which is run on power from hydro stations in the State. Ammonia is made by electrolysis of water, nitrogen being obtained from air by burning a part of the

hydrogen recovered by the electrolytic process. Ammonium sulphate is produced by the sulphuric acid process, elemental sulphur being imported from abroad *via* Madras port. The plant is designed to produce $4\frac{1}{2}$ tons of ammonia a day and 20 tons of ammonium sulphate a day.

Belagula is admittedly not a suitable location for a large fertiliser unit. An expansion scheme is under consideration which, if carried out, will double the production of both ammonia and ammonium sulphate. In the absence of any natural advantages there is no proposal for extending the capacity of the Belagula plant any further.

The scheme which the Mysore Government have referred for our consideration is one which was prepared about three years ago and visualised manufacture of 30,000 tons of ammonium nitrate per year at Bhadravati. At one stage the Mysore Government seem to have proceeded very far indeed with the scheme which, as originally prepared, contemplated production of nitro-limestone. On the strong recommendation of Dr. Frank Parker of T.C.M., said to have been made after a study of Mysore crops, soils and climate, the scheme was altered later to one of production of pure ammonium nitrate in a prilled form. An American firm (Chemical Construction Corporation of New York) was engaged as Consulting Engineers and the World Bank approached for a loan which, we understand, was very nearly sanctioned. The scheme had, however, to be shelved for the time being because it transpired that the necessary quantum of power* (25,000 K.W.) would not be immediately available. After the integration of Mysore, whatever power was available from Jog falls (of the order of 120,000 K.W.) was utilised for more urgent purposes in neighbouring areas in Bombay, Madras and Coorg. Now that there is a scheme to build two other dams on the same river near Gersoppa (known as the Honnemaradu scheme), which will yield 400,000 K.W. initially going up to 700,000 K.W. ultimately, the Mysore Government are anxious to revive the fertiliser production scheme. We were told that on the completion of the Honnemaradu project (which is estimated to cost between 30 and 40 crores), abundant electricity will be available to justify production of ammonia by the electrolytic process. The present cost of power generation at the Jog falls is, we understand, 2 pies per unit and the future cost after the completion of the Honnemaradu scheme is likely to be still lower. With this low cost power, production of cheap ammonia is a possibility from which nitro-limestone can be economically made as the end-product, dolemite and limestone being available in bulk in the neighbourhood. Alternatively, ammonium sulphate or sulphate-nitrate can be produced utilising imported sulphur *via* Mangalore port. It will be necessary in that case to build a new railway line to connect Mangalore with Hassan—a distance of about 100 miles—to establish railway connection between Mangalore and Bhadravati. It will, of course, be difficult and expensive (though not impossible) to make urea, or ammonium sulphate from indigenous or imported gypsum, because of lack of availability of carbon dioxide as a co-product.

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* It has been mentioned to us that a suggestion was made to the Mysore Government to utilise, as a source of hydrogen, the furnace gases of the electric pig iron plants so as to reduce the demand for power. It does not appear that the suggestion was followed up by the concerned authorities. The furnace gases would not by themselves yield more than about 40 to 45 tons of ammonia per day.

The State Government's proposals as summarised above make it clear that any scheme for establishing manufacture of nitrogenous fertilisers at Bhadravati must be regarded as definitely a matter for the future. The Honnemaradu scheme is, we understand, at present before the Planning Commission and the Mysore Government expect that it would be included in the next five-year plan. Even if the project is given high priority, electric power would not be available from this source until the project is executed. Apart from this, ammonium nitrate or nitro-limestone is not yet an acceptable fertiliser to the Ministry of Agriculture even for local consuming areas in Mysore where some of the soils are said to be non-alkaline. If double salt is to be produced, sulphur will have to be imported and if imports *via* Madras port are ruled out on account of high cost of inland transportation, a 100 miles rail link between Mangalore and Hassan will have to be built to give access to the Mangalore port which is very much nearer. We consider, in these circumstances, that the idea of establishing a large nitrogen fixation plant at Bhadravati has to be deferred till the next instalment of expansion of indigenous production of nitrogenous fertilisers when, we may hope, the Ministry of Agriculture may be prepared to advocate the use of not only ammonium nitrate fertiliser (either pure or diluted with limestone) for the areas for which Bhadravati may be regarded as a convenient supply centre but also perhaps the direct application of liquid ammonia of which, we would like to mention, the Mysore Minister of Agriculture Dr. R. Nagan Gowda is an earnest and ardent advocate. In discussion with us Dr. Gowda was of the emphatic view, based on the experiments he has personally made, that use of liquid ammonia as a nitrogenous fertiliser is both feasible in Mysore and would be acceptable to the average cultivator. Taking into account the present trends of expert opinion we have, however, to regard all this as a matter of future development and conclude that at the moment there is little or no practical scope for establishing a large nitrogen factory anywhere in Mysore to produce any of the end-products specifically mentioned in our terms of reference.

(iii) MADRAS

The recommendation of the State Government is that one of the new production units should be located at Neyveli in South Arcot district and based on the utilisation of the local lignite reserves. We have been referred to the report of Powell Duffryn Technical Services Ltd., on the Neyveli lignite project where several alternative integrated schemes have been recommended for the development of a number of industries at Neyveli, for example, lignite briquetting, low-temperature carbonisation, generation of thermal power, production of fertilisers and manufacture of synthetic oils. The types of fertilisers recommended are urea and ammonium sulphate and, for the production of the latter, the utilisation of imported sulphur or, alternatively, the gypsum deposits in the adjoining Trichinopoly district has been suggested.

While dealing with raw materials in Chapter III we have explained the potentialities of South Arcot lignite reserves and the nature and magnitude of the mining problems which await solution. We have, in the same Chapter, indicated our views on the possibility of utilising Trichinopoly gypsum for manufacture of ammonium

sulphate/sulphate-nitrate at Neyveli. The reserves of South Arcot lignite and Trichinopoly gypsum are in our view invaluable national assets and we have no manner of doubt that once the problems and difficulties in the way of their proper utilisation are satisfactorily overcome, Neyveli would be an ideal location for a large fertiliser production unit.

Neyveli is already well served both by road and rail communications. It is itself a railway station on the Cuddalore-Vriddachalam section of the Southern Railway, and is 23 miles away from Cuddalore port on the Bay of Bengal, 152 miles from Madras and 46 miles from Trichinopoly. With all these places Neyveli is satisfactorily connected both by excellent roads and by rail. The rail-head for Trichinopoly gypsum is Ariyalur with which Neyveli is connected *via* Vriddachalam, the distance involved being 45 miles.

As an alternative to the utilisation of local gypsum for the manufacture of ammonium sulphate, the situation of Neyveli near a minor port lends itself to the use of imported gypsum or pyrites or sulphur. After our visit to Cuddalore port we were left with the impression that the port is capable of being developed into a good all-weather port handling a good deal more traffic than what it is doing at present. Even now there is 3,000 ft. of wharfage with adequate railway sidings on the bank of a tidal river which is 8 ft. deep at low water. There is a sand bar at the point where the river falls into the sea and the depth there is about 3 ft. during low tide and 5 to 6 ft. during high tide. The anchorage for sea-going vessels is at the six-fathom line, about 1½ mile from the port by the river route, but a mile-long jetty from the shore would probably give access to it. The present handling capacity of the port is about 1,000 tons per day, the main commodity imported being coal from Calcutta. A fleet of lighters, each of 50 tons capacity, is maintained by Parry & Co. who are the shipping agents for the port. Since the lighters do not draw more than 3 ft. of water, they sail to and from the anchorage both during low and high tides. Interruptions occur only occasionally during the North East monsoon season in October and November.

In dealing with the question of water supply for plants and factories located at Neyveli, Powell Duffryn have indicated that the source of water would be the mine drainage system but "in the event of there being insufficient mine water to supply the demand of the factories and power station, a pipe line from the Walaja tank will be necessary to supply the balance. The level of the Walaja tank required for irrigation purposes can be maintained by the Veller River Barrage and if necessary sufficient water can be released from the Mettur Dam as an emergency measure." The artesian basin in the region is seemingly so large that we have little doubt that the water requirements of any factory at Neyveli can be adequately met by the pumping of confined water which is, in any case, necessary for winning the lignite. Powell Duffryn have suggested that the artesian water should feed a main storage which would provide about 7 days' storage capacity and should be kept full, quantities surplus to the requirements being delivered into the local irrigation system. The Walaja tank which covers an area of roughly 2½ sq. miles and is at one end of the lignite field would function as a balancing reservoir.

As a possible location for a fertiliser production unit Neyveli has obviously great promise provided the present expectations are not

belied by the further investigations, tests and experiments that have been set in train. We refer, in this connection, to our observations in Chapter III which will indicate the elements of uncertainty in the present situation and also the ground that has still to be covered by way of proving and investigations. We have on the whole thought it proper to assume for our purposes that the results of the further experiments and field investigations now in hand will turn out to be satisfactory and that economic exploitation of the Neyveli lignite will prove to be feasible. On this assumption and on the basis of the costs of power, water, lignite, etc. estimated by Powell Duffryn (for which we cannot, of course, accept any responsibility), we have calculated the cost of production of the specified types of fertilisers in a factory located at Neyveli utilising Trichinopoly gypsum. We would like to emphasise, however, that no completely reliable data about Neyveli economics would be available until Powell Duffryn's tentative scheme has been revised in the light of the final results of the further experiments and tests that are now in progress.

(iv) ANDHRA

The Government of Andhra have pressed on our attention the claims of Vijayawada as an excellent location for one of the new fertiliser production units from the point of view of not only available facilities but also the local demand for fertilisers, both actual and potential. Vijayawada, it has been pointed out, is the heart of the richest and most fertile deltaic region south of the Vindhyas, being served both by the Krishna and the Godavari as well as by an elaborate canal irrigation system founded on the Krishna barrage at Vijayawada and the barrage on the Godavari at Rajahmundry. We have been invited to consider the feasibility of cheap production of the nitrogenous fertilisers mentioned in our terms of reference at Vijayawada using coal from the Singareni coal fields in Hyderabad (a distance of 110 miles) and sulphur imported from abroad by sea route *via* the ports at Masulipatam or Kakinada.

As a possible location for a fertiliser factory Vijayawada enjoys certain advantages which may be briefly recounted as follows: —

In the first place, Vijayawada is the nerve-centre of a network of road, rail and canal communications. It is the meeting place of the trunk roads connecting Calcutta with Madras and Hyderabad with Masulipatam. Being a junction of metre and broad gauge, it offers unique advantages* in rail transportation facilities, both for incoming raw materials and for out-going end-products. The Buckingham canal connects the port at Kakinada with Madras† through Rajahmundry and Vijayawada and is throughout navigable by country craft with an average capacity of 50 tons drawing up to 5 ft. of water. There is a branch canal from Vijayawada to Masulipatam giving access to the open sea. The anicut on the Krishna river at Vijayawada is at the moment being renovated; we found the work in full swing and judging by the progress that has already been made, we estimate that long before a new factory can be built and commissioned at Vijayawada the old anicut will be replaced by a modern regulator with 7 ft. high shutters topped by an all-weather road.

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* Please see, however, in this connection, para 10 (3), chapter V.

† The Buckingham canal goes further south beyond Madras and ends at Mahavalipuram.

Secondly, the port facilities available at Kakinada and Masulipatam (with both of which Vijayawada is connected by canal and river) offer advantages of relatively economic import of raw materials like sulphur or gypsum. Masulipatam is the nearer port being at a distance of only 50 miles from Vijayawada, but as a port Kakinada is probably better* in that it is more sheltered and has a bay which can be developed into a first class port, if ever inland traffic justifies it. Both the ports are located at the end of navigation canals and at both of them transhipment is involved from flat bottom dhows fit for shallow water canal navigation to 50 ton lighters; at either place transportation by lighters from port to anchorage is somewhat expensive at present. During our inspection of the Masulipatam port we concluded, however, that with more regular traffic and better organisation, the current loading and unloading charges and cost of transportation from port to anchorage in the open sea about 6 miles or so away can be considerably reduced. Both the Vijayawada-Masulipatam canal and the Rajahmundry-Kakinada canal are navigable for something like 10 months in the year.

Thirdly, a factory located at Vijayawada would be able to get all its water supply at little cost from the reservoir above the anicut. Even at present the minimum flow of the Krishna near the Vijayawada anicut is of the order of 400 cusecs in the driest month. The analytical data of Krishna water in the nearby canal, which we obtained from the local Power House are satisfactory. The water is muddy for half the year and would require clarification for factory use.

Fourthly, a factory at Vijayawada would be able to take advantage of the hydro-electric power available from the Machkund hydro-electric system. Vijayawada has at the moment a small power station with an installed capacity of 12,000 K.W. but its connection with the Machkund hydro-electric system is imminent; we understood that by the middle of 1956, 51,000 K.W. of hydro-electric power would be available, apart from Andhra's share of additional power from Jalapat dam† which is now under construction. This additional power (of the order of 42,000 K.W.) will be available by 1958. A factory at Vijayawada would thus be able to purchase hydro-electric power at a reasonable rate and need only have a small thermal station sufficient for the production of the required quantity of process steam. The Andhra Chief Engineer, Electricity, in fact gave us to understand that even process steam can be made available from a new thermal station of 30,000 K.W. which will have anyhow to be built to

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* Kakinada is also less liable to cyclonic storms than Masulipatam, has more space, more wharfage and better handling facilities, being able to handle 800 to 1000 tons a day as against Masulipatam's 600 tons a day on the average. To quote from Mr. Nanjundiah's Report on Survey of Minor Ports, "from engineering and marine points of view Kakinada offers the possibilities of a potential all-weather harbour without the evils of sand drift and maintenance dredging to the same extent as at Madras and Vizagapatam".

† The Jalapat dam will not have any hydro-electric installation; but the reservoir will serve not only as a storage for irrigation but also as a balancing reservoir to ensure steadier generation of firm power. On the completion of the dam, availability of firm power will be of the order of 102,000 K.W. of which Andhra's share is 70 per cent and Orissa's share 30 per cent.

buttress the hydro-electric system and for which Vijayawada is as convenient a location as any other place in this neighbourhood.

Fifthly, Vijayawada is to some extent already industrialised. Not only have several light industries been established in the town and in its immediate vicinity but a licence has recently been recommended by the State Government for a Calcium Cynamide factory; in addition there are sizeable factories for the manufacture of phosphatic and mixed fertilisers and an A.C.C. Cement factory. There is, besides, an Irrigation Department workshop in respect of which a scheme of extension has recently been sanctioned at a cost of Rs. 25 lakhs. Availability of skilled or unskilled labour would thus present no difficulty.

The advantages enumerated above are in our view weighty enough to justify a full investigation of the potentialities of the location. We have accordingly collected necessary data for a reasonably accurate estimate of the costs of production of double salt and urea at Vijayawada with a view to compare them with likely costs of production at other locations having comparable advantages. The calculations have been made on the following among other assumptions:

(1) Cost of water has been assumed to be actual cost of pumping plus the P.W.D. fee of Re. 1 per thousand cubic yards of water.

(2) Availability* of hydro-electric power has been assumed at 6 pies per unit. Actually the revenue rate is, we understand, Rs. 232 per K.W. year or less than 6 pies per K.W. unit.

(3) Cost of transportation of canal has been assumed to be the current normal rate of 1 anna per ton mile.

(4) The cost of Singareni coal delivered at site has been taken to be Rs. 29 per ton delivered at factory site inclusive of railway freight, cess as well as loading and unloading charges. This, we found, is the present cost of Singareni coal delivered at the site of the existing thermal plant at Vijayawada.

(5) On the basis of data collected from the Andhra Cement Company, all-inclusive wages of skilled and unskilled labour have been taken to be Rs. 2/8/- and Rs. 1/4/- per day respectively.

(6) Availability of land at Ibrahimpatnam by the side of the Vijayawada—Hyderabad Trunk Road has been assumed at the average rate of Rs. 2,500 per acre on the basis of the Andhra Government's report. We have been assured that the site is well above the highest flood level recorded so far but have not investigated the bearing strength of the local soil. Should the bearing strength prove to be inadequate, a site will have to be selected on the right bank of the Krishna about two miles away from the river. That will add to the cost of pumping water.

(v) ORISSA

The State Government's proposal assumes utilisation of gas from the coke ovens due to be installed as an integral part of the Rourkela

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* In a telegram dated the 19th April, Andhra Government have confirmed that supply of 40,000 K.W. of hydro-electric power "can be confidently relied on" by June 1957 and that "up to 15,000 K.W. can be supplied earlier by December 1956"; also that the rate for power "will not exceed" six pies per unit.

Iron and Steel Plant. The specific suggestion that was put forward for our consideration during our visit to the State was that the gas should be stripped of its hydrogen content which would then be utilised for ammonia synthesis, the hydrogen-free gas being returned to the steel plant. The steel plant, it is suggested, should replace the heat value lost by removal of hydrogen by utilising extra quantities of coal tar/fuel oil/coal.

In dealing with coke oven gas as a raw material for ammonia synthesis in Chapter III we have specifically examined this suggestion in some detail. We have explained there that although the suggestion was brought to the notice of Messrs Krupp-Demag and the Hindustan Steel Ltd., we have been unable to obtain, till the time of writing this report, an indication of their final views on the issue. If only for this reason it is not possible for us to give serious consideration to the State Government's suggestion.

Apart from the above, we note that there are certain other difficulties about the establishment of the specified types of fertilisers at Rourkela. There would, of course, be no difficulty about water supply or availability of power. Water would be available from the Brahmani and any difficulties about obtaining an all-the-year-round supply will, we expect, be overcome in connection with the installation of the steel plant. Hydro-electric power from Hirakud would, we understood, be available at the rate of 9 pies per unit. The chief difficulties about establishing at Rourkela the specified end products, urea and ammonium sulphate/double salt, would arise, however, in connection with the availability of carbon dioxide and a sulphur radical. We were told that a certain amount of carbon dioxide should be available from the lime and magnesite kilns which the steel plant will have to put up but the quantity available from this source is likely to be sufficient only for a 35 tons/day urea plant. Carbon monoxide in the blast furnace gas is another possible source of CO_2 but special arrangements for its recovery will be necessary and we are not certain whether the steel plant authorities would be agreeable to the proposition nor how it would affect their economies. In the absence of a sufficient quantity of carbon dioxide it will not be possible to adopt the gypsum process for making ammonium sulphate/double salt; in any case transportation of indigenous gypsum from the nearest sources in Rajasthan would involve an unreasonably long haulage. Utilisation of imported sulphur or pyrites must also be ruled out having regard to heavy costs of inland transportation. The only possibility thus of making ammonium sulphate/double salt at Rourkela is utilisation of Amjor pyrites. The deposits at Amjor are not too far from Rourkela; though the distance by rail *via* Dehri-on-Sone is at present about 380 miles, we understand that there is under consideration a proposal to join Birmitrapur with Barkakana on the broad gauge system. Should the proposal materialise, the distance would be reduced to about 300 miles. In dealing with the pyrites deposits at Amjor in Chapter III, we have, however, expressed ourselves against depending on them as a source of supply of a sulphur radical for a fertilizer factory until further explorations are made and the extent of the pyrite reserves is satisfactorily established. Apart from this, should the Amjor deposits prove to be an economically exploitable reserve, it would probably be expedient to utilise it at a location nearer the deposits such as Barkakana, the poten-

tialities of which have been discussed by us in dealing with the proposals of the State Government of Bihar.

On the whole, we consider that in the event of the utilisation of coke oven gas at Rourkela being accepted as a feasible proposition, the best plan would be to make either anhydrous or aqueous ammonia in an integrated ammonia plant or, alternatively, nitro-limestone for which the only other raw material required, namely limestone, is available in plenty in the neighbouring Birmitrapur area. The suggestion is naturally subject to the proviso that liquid ammonia/nitro-limestone will at sometime in future be accepted by the Ministry of Agriculture as desirable and usable fertilisers.

(vi) WEST BENGAL

In West Bengal's memorandum attention has been drawn to a number of advantages in locating one of the new fertiliser production units at Durgapur on the Eastern Railway in the district of Burdwan. The advantages, briefly, are

(1) The D.V.C. barrage at Durgapur would ensure cheap water supply from the reservoir. The supply would indeed be so plentiful that it may be possible to do without cooling tower installations. Raw water can be reasonably costed at 2 annas per thousand gallons.

(2) D.V.C. power would be available at a cost of not more than 0.6 anna per unit. Our attention has been drawn to the fact that the D.V.C. quoted a rate of .56 anna per unit for a proposed steel plant at Durgapur.

(3) The location being on the fringe of the Raniganj coal reserves, supply of coal would involve little transportation costs. The nearest coal is at Ondal which is only 11 miles away. Even coke (as well as coke oven gas when the new batteries are installed) may be obtainable from Burnpur which is 31 miles away.

(4) Durgapur is situated in the heart of an industrially developed area being 98 miles from Calcutta, 27 miles from Asansol and within a radius of 40 miles from industrial centres like Burnpur, Kulti, Kumardhobi, etc. This implies ready availability of skilled workers and engineering and other construction facilities.

(5) Durgapur, has, further, unique communication facilities by road and rail as well as by water. In particular, Durgapur will now be connected by the D.V.C. navigation channel with the Calcutta port which will facilitate economic import of raw materials from abroad by the sea route and also supply of finished product by inland waterways or coastal shipping to Assam, Orissa and Madras and even further South. The cost of water transport between Calcutta and Durgapur would be, we were told, between half and one anna per ton mile.

(6) The D.V.C. construction colony at Durgapur which was built at a cost of half a crore of rupees would be available for a Government factory. The colony has about 350 houses with such essential amenities as hospitals, etc. and would

become almost wholly surplus to D.V.C. requirements after completion of the barrage project. Nearly 150 sq. miles of land is already under notification for acquisition and the cost of land (which is virgin jungle land) is estimated at Rs. 500 per acre. The bearing strength of the soil is well over 2 tons per sq. foot and therefore adequate for heavy factory foundations.

Apart from the above advantages, our attention has been drawn to a Durgapur Development scheme which is now under consideration. The scheme contemplates a 60 M.V. power station and a coke oven battery with a throughput of 1300 tons of coal a day. We were told that as far as the power project is concerned, the State Government has decided to go ahead with it in any case, but the coke oven project is now under the consideration of a Committee appointed by the Planning Commission. Power from the Power Station, which will utilise low grade coal, will be supplied to the D.V.C. grid but process steam can be made available from it for a fertiliser factory at a fair price based on price of coal. If the coke oven project goes through, the coke will be sold in local markets and, according to present plans, the coke oven gas made over to a gas grid for use in Chittaranjan/Asansol/Calcutta. We were informed that in the event of the establishment of fertiliser factory at Durgapur, the coke oven gas would be turned over to it for making synthetic ammonia and the idea of a gas grid will then be given up. The total production of coke oven gas would be 15 m. cu. ft. a day out of which 9 m. cu. ft. would be available for ammonia synthesis, the balance being required for underfiring the ovens.

The advantages summarised above are certainly impressive, even leaving out of consideration the development scheme whose future is somewhat uncertain at the moment. There can be no two opinions that with the available facilities, particularly cheap coal, products like urea and/or ammonium nitrate can be made very cheaply at Durgapur.

The two main drawbacks about the Durgapur location are (1) its close proximity to the large fertiliser production centre at Sindri; and (2) the necessity of importing sulphur or pyrites from abroad (or the long haulage involved in bringing Rajasthan Gypsum) for manufacturing ammonium sulphate or sulphate-nitrate, these being the products we are required by our terms of reference to arrange for, besides urea. Having regard, again, to our terms of reference, we are unable to give serious consideration to the soda ash-cum-ammonium chloride scheme proposed in the State Government's memorandum even though we consider the scheme to be *prima facie* feasible.

Taking into consideration all relevant factors we have nevertheless considered it expedient to assess the economic advantages of establishing a production and supply centre at Durgapur. We have accordingly calculated likely production costs of ammonium sulphate/double salt and urea in a production unit located at Durgapur on the assumption that a fertiliser factory will be set up as an independent scheme taking advantage of available facilities like cheap and plentiful water supply, relatively cheap power from D.V.C. grid. cheap land, availability of water transport, etc., etc. Inland water transport charges have been taken to be 1 anna per ton mile.

Although we have not calculated likely production costs on the assumption that the Durgapur development scheme now under consideration will materialise and that a fertiliser production unit will be set up in association with it, utilising process steam from the Power Plant and coke oven gas from the coke oven plant, we note that the production cost of ammonia in a 170 tons/day ammonia plant (based on the availability of 9 million cu. ft. of gas per day) will be about Rs. 65 per ton lower than the cost of making ammonia which we have calculated on the basis of gasification of local coal (Annexure VIII).

(vii) ASSAM

The chief factor which favours the establishment of a nitrogen fixation factory in Assam is its abundant coal reserves. Assam coals are somewhat dissimilar to other Indian coals, being rich in sulphur, low in ash and moisture and having a high volatile content. Though caking they are not suitable for making metallurgical coke. On the other hand, they are eminently suitable for ammonia synthesis by the process of direct and complete gasification. In fact, we have been assured on reliable authority that the best utilisation of Assam coal is its gasification for ammonia synthesis. The sulphur content of the coal is unusually high and goes up to 6 per cent for certain seams. To the extent that Assam coals may be used for gasification with a view to synthesis of ammonia, sulphur can, we understand, be easily recovered by a relatively simple process.

Location of a fertiliser production unit in Assam would be attended by certain other advantages also. The Brahmputra and many of its tributaries being perennial rivers, supply of water in any quantity would present no difficulty. Also, the local requirement of nitrogen is fairly considerable. We have been assured that even now the tea industry (covering Assam as well as the North Bengal area) consumes every year 10,000 tons* of nitrogen mostly in the form of ammonium sulphate or mixed fertilisers, and the Assam Government may not be very far off the mark in estimating that the potential fertiliser demand, likely to materialise by 1961, would be of the order of 50,000* tons of nitrogen per year.

In the light of the above considerations the suggestion of the Assam Government is that one of the new fertiliser production units should be established in the neighbourhood of Pandu/Gauhati for the manufacture of urea and ammonium nitrate diluted with limestone. Limestone is reported to be available in the Cherapunji hills which, as a crow flies, are near enough. Transportation of coal is assumed from the Khasi hills which again, geographically, are reasonably near the suggested location. It has been claimed that if nitro-limestone is dusted with 5 per cent Kaolin and specially treated with 1 per cent rosin and/or paraffin and asphaltum (which are readily obtainable from Assam oil wells), the end product would be rendered comparatively non-hygroscopic and would have as satisfactory keeping qualities as ammonium sulphate or any type of mixed

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* The Agriculture Ministry's estimate of nitrogen requirement in Assam by 1960-61 (Annexure IV) thus appears to be somewhat low.

fertiliser now commonly used in Assam. A reference has been made also to the possibility of cheap hydro-electric power being available from the Umtru project consisting of a barrage on the Umtru river (a tributary of the Brahmputra) and a hydro power station, the site of the barrage being 15 miles from Gauhati. The barrage is already under construction and in the first phase 7,500 K.W. of hydro-electric power would be available, the second phase power generation being estimated to be of the order of 95,000 K.W.

We have given earnest consideration to all the factors briefly listed above, but have regretfully come to the conclusion that there is at present no possibility whatsoever of establishing economic production of any type of nitrogenous fertiliser either in Pandu area or at any of the other alternative locations suggested by the Assam Government, viz., Dudnoi near Goalpara at the foot of the Garo hills and Naharkatiya near Dibrugarh in the vicinity of the recently discovered oil fields.* The chief difficulty (and the difficulty is almost unbelievable) is about transportation. Although the geographical distance between the Gauhati-Pandu area and the Khasi coal mines is not very great (about 60 miles or so) the absence of communication facilities and the natural mountain barriers intervening in between render transportation difficult, slow, and extremely expensive. While the pit-head price of coal in the Khasi mines is only Rs. 10/8/- per ton, its selling price at or near Gauhati, only 60 miles away, is at the moment Rs. 60 per ton. Reference has been made to a ropeway project for connecting Cherapunji with Brahmaputra Valley for which, we understand, surveys are now being made. The project, if approved, is however likely to be included in the Second Five-Year Plan and is thus definitely a matter for the future. Even when the ropeway is built, the cost of coal delivered at or near Gauhati would still be of the order of Rs. 25 per ton.

A further difficulty arises from the fact that we are required by our terms of reference to arrange for the establishment of production of ammonium sulphate or sulphate-nitrate in addition to urea. It would not be a feasible plan to depend on sulphur recovered from Assam coals as a raw material for the manufacture of ammonium sulphate or double salt. In spite of the high content of sulphur in Assam coals, it will be necessary to handle an enormous quantity of coal (for which it is at present quite impossible to find ready use) to recover the quantity of sulphur required for even a moderate sized plant for the production of ammonium sulphate or double salt. The other alternative of importing sulphur or gypsum from abroad or bringing gypsum from Rajputana has also to be ruled out because of high transportation costs. Even the cost of transportation by steamer would be prohibitive, apart from the fact that the steamer route lies

* The possibility of processing natural gas from the Naharkativa wells has been adverted to in the Assam Government's memorandum. We have seen, however, a recent letter from the Assam Oil Company where it has been explained that nothing can be said about the future availability of surplus gas from the Naharkatiya wells until after two years or so. It has accordingly been suggested that the possibility of gas supply from Naharkatiya should not be allowed to influence the siting of a fertiliser plant under the present expansion programme. As far as the old wells are concerned, we gather that no surplus gas is available from any of them; whatever little gas is yielded is required for the working of the wells.

partly through the foreign territory of Pakistan. We understand that at the moment steamer freight charges from Calcutta port to Pandu along the Brahmaputra are Rs. 1/2/6 per maund for loads of over 200 tons, the rate for loads of 200 tons and under being Rs. 1/14/- per maund. In addition, there is a customs levy of 1 anna per maund and Port Commissioners' charges at the rate of 6 annas per ton. It is obvious that after adding these high freight charges, to the landed cost of imported gypsum or sulphur at Calcutta port, the final cost of gypsum or sulphur delivered at factory site would be so high as to render economic production of fertilisers an impossible proposition.

These are briefly the reasons which have led us to conclude that as matters stand at present any location in Assam has to be ruled out. We are nevertheless impressed by the fact that the best way to utilise the valuable Assam coals is to gasify them for ammonia synthesis and we suggest that when the State has further developed and transportation situation becomes easier, the position should be carefully reviewed and the possibility of locating a fertiliser unit under the next expansion programme should be considered afresh on its merits, provided the Ministry of Agriculture is by then prepared to accept (1) that nitro-limestone treated in the manner suggested in the Assam Government's memorandum (or in some other more suitable manner) will have satisfactory keeping qualities even under adverse climatic conditions of high humidity and (2) that this end-product along with urea are suitable and beneficial fertilisers for the tea crop. As far as we can judge, production of ammonium sulphate or sulphate-nitrate would never be an economical proposition in Assam unless of course extensive gypsum deposits are discovered in the State in future.

(viii) BIHAR

In December 1954 we received from the Bihar Government a suggestion for the location of one of the new fertiliser production units at Barauni junction in the district of Monghyr in North Bihar. The location at Barauni was suggested with particular reference to its admirable situation as a supply centre for a large as well as rich and fertile consuming area in not only North Bihar but also North Bengal, Assam, Manipur and Tripura, the eastern parts of Uttar Pradesh and even Nepal and Bhutan on the border of India. While conceding, however, the advantage which a fertiliser production unit at Barauni would have from the supply and distribution point of view, we must point out that as a production centre it would be handicapped by its great distance from the sources of either of the two principal raw materials, namely, coal and gypsum. It would be expensive to bring coal from Jharia or Karanpura coal fields; and transportation costs for gypsum from Rajputana would also be equally heavy. Further, until the Mokama bridge is completed, transport of coal or gypsum to the factory site would involve ferrying them across the river; and even after the bridge is completed it will involve transhipment from broad gauge to metre gauge until Barauni is connected on the broad gauge line.

These drawbacks have been discussed with the State Government's representatives; in the result fresh proposals were put up for the Committee's consideration at the time when the Committee visited Dalmianagar towards the end of March 1955. Two alternative locations have been suggested in the State Government's new proposals, viz., (1) at Barkakana in the district of Hazaribagh and (2) near Haidernagar in the Son Valley on the right bank of the Son immediately after its confluence with the North Koel and almost opposite the Rohtas fort on the left bank.

The Barkakana site is on the edge of the extensive South Karanpura coal reserves and only 7 miles away from the coal loading railway station at Bhurkunda. Barkakana is a railway junction of some importance connecting the Gomoh-Sone-East-Bank loop line with Tatanagar, Kharagpur and Calcutta. The site suggested for the location of the factory is in close vicinity of Ramgarh military encampment and is connected to the Ranchi-Hazaribagh trunk road by a four miles long metalled road.

We were given to understand that after the expansion of the Bokharo thermal station D.V.C. power is likely to be available for a fertiliser factory at Barkakana, the cost of power being approximately 0.7 anna per unit. The chief advantage of the Barkakana site is, however, that it is within a convenient distance of both limestone deposits of excellent quality as well as ample coal reserves—both limestone and coal being within a radius of 10 miles. It is thus an excellent location for a factory designed to manufacture nitro-limestone but it suffers from the disadvantage that special measures will be necessary to ensure continuous water supply throughout the year. Although Barkakana is on the bank of the Damodar, it is not downstream of any of the D.V.C. reservoirs for which reason it would in all probability be necessary, presumably with the permission of the D.V.C., to build a low barrage or anicut on the river or, alternatively, make arrangements similar to those made for the security of factory water supply at Sindri.

The other site recommended for the Committee's consideration is a mile and a half northwest of Haidernagar railway station on the Son-East-Bank-Barkakana-Gomoh loop line and is close to the Japla Cement factory. Here also excellent limestone deposits are available within 5 miles as a crow flies but on the other side of the river. For a nitro-limestone factory on this site, therefore, limestone will have to be brought from the Rohtas side of the river by ropeway as indeed the Japla Cement factory is doing at present. The nearest coal deposits are at Daltonganj 30 miles away and at Hutar 60 miles away. The Daltonganj deposits are reported to be of the order of 9 million tons only and have not been properly worked so far. A factory at this site will thus probably have to depend upon the Hutar coal fields. There would be no difficulty about securing the necessary quantity of water from the Son which at this point, we were assured by the State Irrigation Engineer in charge, has a minimum flow of 1,000 cusecs in the driest month.

Both the sites suggested by the State Government have potentialities provided the end product to be established is nitro-limestone; since, however, we are precluded from considering this product by our terms of reference, we have not considered it necessary to make a closer study of either of the two locations. We would, nevertheless,

add that if according to the suggestions we have made in Chapter III the Amjor pyrites deposits are explored further and it transpires that the pyrite reserves are of such magnitude as to justify their economic exploitation, the Son valley site near Haidernagar railway station would be a good location for establishing either an ammonium sulphate or a sulphate-nitrate factory in association with an urea production unit. The Amjor deposits are only 11 miles away from the Haidernagar site as a crow flies but are of course across the Son river.

(ix) UTTAR PRADESH

The specific suggestion put forward for the Committee's consideration is that a fertiliser factory should be located in the neighbourhood of Mirzapur and based on the utilisation of hydro-electric power from the Rihand dam project. The Rihand is a tributary of the Son and the dam site is about 75 miles away, as a crow flies, from Mirzapur, an important station on the Eastern Railway. Mirzapur has been connected by road with Robertsganj, about half way to the dam site, mainly in the interest of the Government Cement factory at Churk 4 miles south of Robertganj. About two years ago a broad gauge rail link was also established between Chunar, the next station after Mirzapur to the east, and Churk *via* Robertsganj.

The dam site at Pipri is about 40 miles south of Robertsganj across the Son. A road is under construction (along with a bridge on the Son) to connect Robertsganj with Pipri. A proposal to connect Robertsganj with Pipri by rail is also, we understood, under consideration.

The suggestion of the State Government is that a fertiliser factory may be conveniently located either at Mirzapur depending on the Ganga for its water supply or in the neighbourhood of Churk with arrangements for supply of water from the Son. In either case it is suggested that the factory should utilise power generated by the Rihand Dam. We were told that the anticipated power generation would be of the order of 240,000 K.W. most of which can be made available for purposes of a fertiliser factory, since the Mirzapur area of U.P. is still undeveloped and, in consequence, there is little local demand for power. The anticipated cost of power generation is 3.47 pies per unit and on this basis it has been provisionally* decided that power will be sold to major industries at the rate of 4 pies per unit. An important fact of which due account must be taken for our purposes is that Rihand hydro-electric power will not, we understand from the Central Water Power Commission, be available till 1960-61.

The end product which can be most conveniently established in the vicinity of Churk, on the basis of utilisation of hydro-electric power, is nitro-limestone in view of the proximity of limestone deposits. Alternatively, sulphate-nitrate can be made along with urea, whether the factory is located at Mirzapur or near Churk, assuming utilisation of coal brought from the Bihar coal fields and gypsum brought from Rajasthan. Utilisation of the newly discovered coal at Singhrauli, which has been suggested in the U.P. Memorandum does not appear to us to be immediatey feasible if only for the reason

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* The final triff will be worked out after the necessary data are available for a firm calculation of cost of power generation.

that the deposits have still to be fully proved and thereafter developed to a state when they can be worked after the establishment of necessary road and rail communication facilities. According to Geological Survey reports the proved reserve in Kota area in Uttar Pradesh is only of the order of 2 million tons, but field investigations appear to have established that "geographically the whole area covered by the Singhrauli coal field forms a single comprehensive unit" and also indicated "that a thick coal seam extends over a wide area in this region" most of which is in Vindhya Pradesh. It is clear that the total reserves in both Uttar Pradesh and Vindhya Pradesh, which have yet to be exactly ascertained, are in all likelihood a great deal more than 2 million tons. The main difficulty about working or even proving the deposits is entire lack of any communication facilities. Even the Kota area in Uttar Pradesh which is about 20 miles from the Rihand dam site at Pipri and 50 to 60 miles from Robertsganj is not yet connected by even a tolerably good road.

It is true that a factory in the Mirzapur-Robertsganj-Churk area will ensure proper utilisation of Rihand hydro-electric power,* but the cost of power would not be low enough to permit economic production of synthetic ammonia by electrolytic decomposition of water. Apart from this, there would be difficulty, if ammonia is made by the electrolytic process, about the production of any of the three fertilisers specified in our terms of reference due to non-availability of carbon dioxide as a co-product. While, however, the idea of manufacturing ammonia by the electrolytic process has, for these reasons, to be ruled out at a factory located at or near Mirzapur and designed to produce urea and/or sulphate-nitrate, it is, we recognise, possible to arrange for economic production of ammonia from coal imported from Bihar coal fields with simultaneous utilisation of cheap hydro-electric power for normal factory operations. This is so because as a raw material electricity plays nearly as important a part in the economics of production of any type of nitrogenous fertiliser as solid raw materials. Even though, however, production economies under the arrangement visualised above would undoubtedly be extremely encouraging, we have been unable to give serious consideration to it chiefly for the reason that Rihand hydro-electric power would be available a little too late for the current expansion programme. According to our terms of reference, the extra production of 170,000 tons of nitrogen has to be established by the year 1961 which means that the new plants must, after completion of construction, be put on stream at least a year beforehand. In order that this programme can be carried out, it is necessary that the full quantum of power should be available by the beginning of 1960 *at the latest*; while even according to present plans, the anticipated date of availability of Rihand power is end of 1960 or beginning of 1961. Again, any delay, which is by no means improbable, in the execution of the Rihand Project will mean further delay in the commissioning of any fertiliser factory that may be approved for this locality and take us a good deal beyond 1961 by which year the new fertiliser production is due to be established. Two other reasons which have influenced our decision are:

(i) as a supply centre for the consuming areas in the west and the south, for which the new production exclusive of

* The Rihand project is purely hydro-electric power generation project and not a multipurpose scheme.

Nangal is being planned, Mirzapur is not conveniently situated. Again, both the solid materials required for the manufacture of ammonium sulphate/sulphate-nitrate, i.e. gypsum and coal will have to be brought to the factory site from places several hundred miles away: Bihar coal would be nearly 300 miles and Bikaner gypsum over 800 miles away from the factory site. The total volume of transportation required for bringing raw materials to factory site and sending out finished products to their destinations would be, we have roughly estimated, nearly 50 per cent in excess of what would be involved for a more convenient location like Itarsi in Madhya Pradesh or Ramagundam in Hyderabad; and

(ii) we consider that with all its advantages the Mirzapur site should be reserved for the installation of a *nitro-limestone cum urea factory. Such a factory should, in our view, be established preferably after the Singhrauli coal fields are fully prospected and developed and it is possible to economically work them after provision of necessary communication facilities. This suggestion has such attractive features that we have dealt with it in some detail in the concluding Chapter.

We have independently considered what seemed to us to be a more suitable location in Uttar Pradesh for a fertiliser production unit based on the utilisation of Rajasthan gypsum, namely, some place in the neighbourhood of Mathura/Agra/Hathras. All these towns have the advantage of being junctions of metre and broad gauge systems which would facilitate transportation of the principal raw materials and also despatch of the end-products by eliminating break-of-gauge transhipment. A factor which we thought, on first consideration, may favour this location is that it would secure full utilisation, on their return journey, of broad gauge wagons taking gypsum to Sindri. We have, however, been assured by Railway authorities (see para 10(8) of Chapter V) that the preponderating flow of goods traffic is from the east to the west and not *vice versa* and consequently there is no problem now of empties coming back to the west from the coal field areas.

Of the three alternative locations Mathura, Agra and Hathras, we have had to rule out the former two partly because they suffer from heavy congestion of railway traffic but mainly because all-the year-round water supply is likely to present a very difficult problem. We understand that the minimum flow in the Jamuna in the driest month is *nil* near Agra/Mathura; further that underground strata conditions at either place are unfavourable. We have thus selected in the end, for further investigation, Hathras which is, geologically, in the same area as Harduaganj near Aligarh which was the first preference of the Technical Mission appointed by Government in 1944 to make recommendations on, among other things, the most suitable location of the first nitrogen fixation factory in India. In selecting Harduaganj the Technical Mission assumed, on the evidence furnished by U.P. Irrigation Engineers, that adequate supply of water

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*We have good reasons to believe that before long nitro-limestone will be acceptable to the Ministry of Agriculture as a suitable fertiliser for acid soils in the east and the south. See Chapter VIII.

can be secured for factory purposes by "a comparatively inexpensive system of tube-wells." The U.P. Government have confirmed our presumption that the same conclusion will hold good in respect of Hathras as well. We were told that some hydro-electric power may be available for a factory in this neighbourhood from the Ramganga project of which, we understand, the firm power yield will be of the order of 30,000 K.W. In discussion with the authorities of the C.W.P.C., however, we gathered that the Ramganga project is still under investigation and has yet to receive approval.

(x) PEPSU

The Government of PEPSU have suggested that a fertilizer factory may suitably be located at Surajpur where there is already a cement factory. The suggested location is 45 miles from Patiala, the capital of PEPSU and only 10 miles from Chandigarh, capital of the Punjab. It has been suggested that the factory should be based on utilisation of coal imported from Bihar coal fields and cheap electricity from the Bhakra-Nangal project.

We have not considered it necessary to give serious consideration to the State Government's proposal, firstly because a fertiliser factory depending for its principal raw material, that is, coal, on sources a thousand miles or more away can hardly be an economic unit and secondly and mainly because, following the directive of Government, we have recommended the establishment of a total production of 70,000 tons of nitrogen a year at Nangal in the form of a suitable type of ammonium nitrate fertiliser. The production at Nangal, which is less than a hundred miles away from Surajpur, will meet the requirements of practically the whole of the northern zone including PEPSU and all its neighbouring areas.

(xi) RAJASTHAN

We have considered four different locations for a fertiliser factory in Rajasthan, namely (1) Hanumangarh; (2) Bikaner city or its neighbourhood; (3) Bharatpur; and (4) Sawai Madhopur. Bharatpur and Sawai Madhopur have an advantage over the other two locations in being junctions of metre gauge and broad gauge railway systems. This would facilitate bringing in raw materials from, and sending off the end products to, places outside Rajasthan. Unavoidable transhipment of certainly the end products and also of Bihar or Madhya Pradesh coal (to such extent as coal may have to be used) will be involved in case a factory is located at either Hanumangarh or in the neighbourhood of Bikaner city which are connected only on the meter gauge system.

Rajasthan has the unique advantage of having both enormous gypsum reserves as well as a 15 million-tons reserve of lignite eminently suitable for gasification for ammonia synthesis. For an appreciation of the potentialities of gypsum and lignite reserves in Rajasthan we refer to our observations on the subject in Chapter III. Almost any location in Rajasthan, particularly Hanumangarh and Bikaner city, suffers, on the other hand, from the disadvantage of being somewhat away from the areas and regions where the new production of 100,000 tons of *nitrogen is expected to be consumed. Further, water supply for

* Leaving aside 70,000 tons N which it has been decided to produce at Nangal.

factory purposes presents a problem of greater or lesser magnitude everywhere.

The location at Hanumangarh is the only one which has been officially sponsored by the Rajasthan Government, and the results of the painstaking investigations that have been made to establish its suitability are incorporated in a carefully prepared printed memorandum (Appendix I). Hanumangarh is situated almost at the northern end of Bikaner division and is 125 miles away by rail from the currently exploited gypsum deposits at Jamsar and nearly 160 miles away from the lignite fields at Palana. It is a metre gauge junction of considerable local importance, the nearest broad gauge junction connected with it being Bhatinda about 65 miles farther north.

For water supply at Hanumangarh it is proposed to depend upon the Bhakra canal system. It has been pointed out that Hanumangarh would be the meeting point of two independent canal systems, the Bhakra canal which will have a flow at this point of 600 cusecs and the Rajasthan or Harike canal with a flow of 16,000 cusecs. We understand that the Harike headworks have already been built but the canal system is unlikely to be laid before 7 to 10 years, and is thus irrelevant in the present context. The Bhakra canal has already been dug upto and for some distance beyond Hanumangarh and was, at the time of our visit, being bricklined. For the time being, the canal will have only a seasonal flow but the supply would be perennial after the completion of the main Bhakra dam, that is about 1958-59. There are certain obvious difficulties about depending on canal water supply for operating a factory. The vagaries of canal water supply are well known; no water would, in any case, be available during "maintenance" periods covering 15 to 20 days a year, apart from which supply is liable to be cut off during high floods and similar emergencies at short notice or even without notice. It is, however, proposed to overcome these difficulties by taking advantage of Regulators on the canal system and by heading up water in a nearby section of the canal to create a reservoir so as to ensure continuity of water supply during any foreseeable difficult period. As a safeguard against unforeseen eventualities (and also for use during the period of construction), it is further proposed to construct one or more storage reservoirs (which will have to be bricklined and brickfloored) with sufficient capacity to meet a full month's factory requirement. Rajasthan Engineers have estimated that one or more reservoirs having a storage capacity of 200 milion gallons capacity or more should not cost more than 40 lakhs of rupees. Our attention has, in addition, been drawn to the fact that there is a perennial flow of underground water at Hanumangarh since the Ghaggar river which rises in the lower slopes of the Himalayas and flows through Ambala, Patiala and Hissar loses itself in the neighbourhood of Hanumangarh. This statement finds support in "The hydrology of the Rajasthan desert" by Messrs. R. D. Dhir and K. V. Krishnamurthy and we do not rule out the possibility of securing a fair quantity of underground water sufficient at least to meet all requirements unconnected with factory operation. During our visit to Hanumangarh, we were shown a Municipal well which, we were told, is pumped for 16 hours every day in two shifts at the rate of 8,000 gallons per hour. The normal depth of water at the commencement of pumping is 33 ft. which is depressed by 8 ft. after two hours of pumping, but thereafter the

water level remains constant inspite of 14 hours continuous pumping. Though the signs are encouraging, it is impossible, without expert verification, to be definite about availability of enough underground water for the operation of a fertiliser factory. On the other hand, we consider that the arrangements proposed for utilising canal water for the purpose are quite feasible. We note that the canal water will be charged for at the rate of 1 anna per thousand gallons.

For power it is proposed to depend on Bhakra hydro-electric power to a large extent. Since the factory will require process steam, a certain quantity of by-product power will be available. As, however, it would be expedient to reserve local lignite for making synthesis gas, steam and by-product power will have to be produced from coal imported from Bihar or Madhya Pradesh. As regards availability of hydro-electric power from Bhakra, a necessary pre-requisite is the strengthening of the transmission lines that have been planned. We understood from the Chief Electrical Engineer of Bhakra-Nangal Project that according to present plans, the high tension main line will come only up to Panipat; from Panipat to Rajgarh, a distance of 140 miles, the line will be a single circuit line and from Rajgarh to Bikaner, a distance of 70 miles, there will only be a 66 K.V. line. This means that if the transmission lines are laid according to present plans, the supply from Panipat to Rajgarh will be of the order of 35,000 K.W. and that from Rajgarh to Bikaner will be only half as much. To make enough* hydro-electric power for factory purposes available at Hanumangarh or at Bikaner it would thus be necessary to strengthen over 200 miles of electrical transmission lines for which the extra capital cost has been estimated to be about †Rs. 15 lakhs in a note furnished to us on behalf of the Rajasthan Government. The Bhakra hydro-electric power would, we understand, be available at 0.6 annas per unit.

On the whole, we consider that the Hanumangarh scheme is feasible enough and we have accordingly calculated the likely production costs of the specified types of fertilisers in a factory located there assuming utilisation of Palana lignite for ammonia synthesis and Bikaner gypsum for manufacture of ammonium sulphate/double salt. We have assumed availability of hydro-electric power, and water supply from Bhakra canal with special storage reservoirs to meet any emergent situation. Since the local soil is mostly alluvium, its bearing strength will require careful testing in case it is ultimately decided to build a factory at Hanumangarh; for the present, however, we have made our cost calculations without taking into account the possible need for special foundations.

We have independently considered suitability of Bikaner city or its immediate neighbourhood for locating a factory because from the point of view of nearness to sources of raw materials, the situation of Bikaner is probably unrivalled in India. There is no other ‡place where the raw material for ammonia synthesis i.e. lignite as well as a

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*Sufficient firm power may not, indeed be available from the Bhakra system because of the heavy requirements of the nitrogen-cum-heavy water plant at Nangal.

† The estimate has not been verified by us.

‡ The closest approximation to this advantage is at Neyveli where lignite is only about 40—45 miles away from gypsum.

suitable sulphur radical for making ammonium sulphate are both available within a radius of 20 miles. Bikaner city is connected by rail with the Palana lignite fields 12 miles to the south as well as with the rich gypsum reserves at Jamsar 20 miles to the north. Both the places are also connected by roads, the road to Jamsar being a Kutcha one but the one leading to Palana and beyond being an excellent metalled road.

The chief difficulty about the Bikaner location is that water supply would be problematic. Through the courtesy of His Highness the Maharaja of Bikaner we have been privileged to have access to a great deal of literature which does *prima facie* indicate the presence of a very considerable quantity of underground water in the Bikaner area. We mention, in particular, the following:

(i) An article entitled "The occurrence of ground water in rocks of western Rajasthan" by George C. Taylor. The article indicates that of all the bed rock formations in Western Rajasthan the Bikaner formation is, geologically, the only one which has some capacity to hold, transmit and yield water. Mr. Taylor observes: "The Bikaner formation contains the regional zone of saturation in the area extending from Bikaner for about 25 miles south, about 20 miles east, and 35 miles to the West and South West. In the city of Bikaner dug and bored wells obtain sustained yields ranging from about 1,500 to 16,000 gallons per hour. The Bikaner formation thus appears to have the most productive water-bearing horizons of any of the bedrock formations of western Rajasthan. The regional water table lies at depths ranging from about 200 to 350 ft. below the land surface. The water levels in wells of the city of Bikaner are at depths of 250 to 350 ft. below the surface".

(ii) A passage in "Hydrological research in the arid and semi-arid regions of India and Pakistan" by Mr. R. D. Dhir, Director (Hydrology), Central Water and Power Commission which runs as follows: "Pickering records that a well at Palana gave a yield of 20 thousand gallons a minute (an hour?). He thinks that there is a great amount of ground water in the Bikaner area derived from the snow-fed rivers of the Himalayas".

(iii) "The Hydrology of the Rajasthan Desert" by Messrs. R. D. Dhir and K. V. Krishnamurthy where a reference is made to a sketch prepared by Mr. Auden (presumably Mr. J. B. Auden of the Geological Survey of India) of "ground water basins which include parts of Bikaner". Messrs. Dhir and Krishnamurthy have recommended, in view of available indications of existence of ground water in Bikaner area, that "efforts should be made to investigate and develop these resources."

Though the evidence, both direct and indirect, of the presence of a considerable reserve of underground water in the Bikaner area including Palana is impressive, we are unable to say that it is conclusive or such as would justify the installation of an expensive factory on the hypothesis that sufficient underground water supply would be available for its operation. Dependence on underground water for running a factory is rare but not, of course, unprecedented.

We found in Dalmianagar that the entire group of Sahu-Jain factories depend for their water supply on 8 or 9 tubewells each yielding a minimum supply of a million gallons of water a day. A well endures for 10 to 15 years and when it gets choked up all that is necessary is to bore a fresh one only a hundred feet or so away. The underground water basin at Dalmianagar is seemingly large enough to sustain a continuous yield of 10 million gallons a day or more indefinitely; and it is not improbable that the Bikaner ground water basin has similar potentiality. We refer also to the fact that the Technical Mission appointed by Government in 1944 recommended Harduaganj near Aligarh in Uttar Pradesh as the most suitable location for an ammonium sulphate factory relying for its water supply on "a comparatively inexpensive system of tubewells". Underground water has, indeed, from certain points of view, an advantage over surface water since, unlike the latter, it is not affected by local failure of rains and is not, moreover liable to evaporation and has not to be led over long distances by pumping or by gravity along expensive canals or metal pipes. We consider, nevertheless, that if underground water at Bikaner has to be depended on for operating a factory in the neighbourhood, the resources should be exactly and definitely established after full investigation by a competent and expert organisation.

Apart from underground water we were told during our visit to Bikaner that the approved alignment of Rajasthan canal would take it within about 20 miles from Bikaner city. We were told also that there is a very large lake at Kolayet about 30 miles from Bikaner which is fed by rain water and from where surface water can be brought for factory purposes, particularly if the security of the reservoir is safeguarded by connecting it with the Rajasthan canal by a bricklined channel. These are certainly possible expedients but we have not considered it necessary to investigate their feasibility in detail at this stage, particularly as the Rajasthan canal will not be established for several years to come. Even though we have, with some *regret, excluded Bikaner from further consideration in the present programme, we suggest that resources of underground water in the Bikaner area should be fully investigated, and the results of this expert investigation should be available in time to consider Bikaner once again in the next expansion plan.

Bharatpur is another location in Rajasthan which though admirable from many points of view has the same problem about availability of water. Its chief merit is that it is a convenient junction of broad and metre gauges and is nearer to consumer points than either Hanumangarh or Bikaner though it is some 350 miles away from Rajasthan gypsum reserves and over 600 miles away from Bihar coal. Like Bikaner, Bharatpur claims existence of a large underground water basin; in support of this claim our attention has been drawn to the existence of a number of tube wells in Bharatpur city and its neighbourhood whose yield is copious and constant and none of which has ever been known to go dry. Our attempts to secure authoritative evidence of ground water in the neighbourhood of Bharatpur have not however met with much success. Another difficulty is that most

* In view of Bikaner's excellent situation near the two principal raw materials required for manufacture of any or all of the three fertilisers specified in our terms of reference.

of the wells at Bharatpur yield highly saline water which will be unsuitable for factory purposes; the salt content of local well-water is indeed so considerable that salt making is, we understand, widely practised in the area. Apart from underground water, there is, we understand, a proposal for the supply of some water to the Bharatpur area through the Agra canal. The proposal is, however, at the stage of discussion, the Punjab being a rival claimant for the same waters; and even if the claim of Rajasthan is ultimately upheld, the supply would, we understand, be seasonal and only for the duration of "the flood months in the Yamuna river." We have not, in all these circumstances, made any independent cost calculations for a factory located at Bharatpur; but note that the economics of this location would not materially differ from those of Hathras for which detailed calculations of probable production and distribution costs have been made.

The fourth and last location we have investigated is Sawai Madhopur near the confluence of the Banas and the Chambal. This is also a junction of metre gauge and broad gauge systems, almost equidistant from the Chambal and the Banas, both being within a distance of 15 to 20 miles from the railway station. If a factory is located here, it will not be possible to utilise Palana lignite in view of the inexpediency, for more than one reason, of transporting lignite over any considerable distance. A factory at Sawai Madhopur would, we have assumed, have to be operated on the basis of coal brought from Madhya Pradesh and gypsum from Bikaner or Jodhpur. Water supply should be secure after the execution of the first stage of the Chambal project since the location is down stream of the Gandhisagar dam (which will have a live storage of over 5 million acre feet) and Kotah barrage. We have been given to understand that a minimum flow of 25 cusecs would be available in the Chambal even in the driest month after the dam and the barrage are built. Special arrangements will have, of course, to be made to bring the water by pumping over a distance of about 10 miles involving a fair amount of extra capital expenditure which will be reflected in the cost of *water. As regards availability of Chambal hydro-electric power, the position is that in the first stage of the project, which is expected to be completed by 1959-60, 3 units of 23,000 K.W. each will be installed at the site of the Gandhisagar dam but the total available power will be shared equally between Madhya Bharat and Rajasthan. This makes it uncertain† whether even a minimum quantity of hydro-electric power will be available for a fertilizer factory. Apart from this, the

*Alternatively, a dam or a barrage could be built on the Banas and the factory located near it and the broad gauge railway bridge; but though this will obviate the need for pumping water over a long distance, it will involve the construction of about fifteen miles long metre gauge siding. The Banas with its 18,866 square miles of catchment area (having an average annual rainfall of 28") offers good potentialities for a reservoir barrage. Although in dry weather the minimum discharge drops to only a few cusecs, the maximum flood discharge of the river is reported to be over 800,000 cusecs. We understand in fact that the Rajasthan Government have some sort of a barrage project in mind at a place much farther up and nearer the source of the river.

†In a telegram dated the 12th May 1955, Rajasthan Government have confirmed that the required quantity of power will not be available for a fertilizer factory.

cost of generation in the first stage is, we gather, likely to be high and it is unlikely that a rate of less than 0.8 annas or 9.6 pies per unit will be charged. Despite this drawback the location has in our view such encouraging potentialities as to merit further investigation: and we have accordingly included Sawai Madhopur in addition to Hanumangarh in the list of locations selected by us for detailed cost calculations. In doing so, we have assumed that a fertilizer factory at Sawai Madhopur will instal its own thermal plant based on Bihar/Madhya Pradesh coal.

(xii) MADHYA PRADESH

The chief advantage claimed by the Madhya Pradesh Govt. for the location of one of the new fertilizer production units in the neighbourhood of Itarsi is that the nearby coal deposits in the Kanhan-Pench-Tawa valleys are nearest the gypsum deposits in Rajasthan and Saurashtra. It has, therefore, been urged that of all places in India ammonium sulphate can be most economically made, utilising indigenous gypsum, at Itarsi or a place conveniently near it.

The actual location suggested for a fertilizer factory is about five miles away from the site of the †dam which it is proposed to construct on the Tawa river, a tributary of the Narmada. The dam site (at village Ranipura) is about 12 miles away from Itarsi, a mile below the confluence of the Denwa stream and the Tawa and 3 miles above the railway bridge on the Tawa between ‡Belawara and Bagra railway stations on the Bombay—Calcutta trunk line.

The site suggested for a fertiliser plant covers an area of about 15 square miles; its northern boundary runs parallel to the Calcutta—Bombay railway line and is within a distance of about half a mile or so from it. The northern two-thirds of the site is alluvium (probably black cotton soil) but the southern one-third is firm rocky (though fairly level) land§ on the Satpura foothills. A short rail link‖ (not more than two miles or so) will connect the factory site with the Calcutta—Bombay line; in addition a railway extension of about 10 miles or so would be necessary to connect the site with the main Delhi—Madras line near Kiratpur railway station. This latter extension is essential to bring the Pathakhera coalfields within a distance of 50 miles from the factory site.

The Tawa scheme is a multipurpose scheme. The dam would create a reservoir of 2.9 million acre feet capacity, and the water would be utilised to generate 13,500 K.W. of power at 100 per cent load factor and 22,500 K.W. at 60 per cent load factor, the installed capacity of the generators being 30,000 K.W. The hydro-electric power is not, however, of much significance in the context of the establishment of a fertiliser factory; we have been advised that a fertiliser factory built in the neighbourhood of the dam should have its own thermal plant to be connected in due course with the hydro-electric power, when it is available, as well as with the Madhya Pradesh

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† The Tawa project has, we understand, encouraging prospects and is very likely to be included in the second five year plan.

‡Belawara is an abandoned railway station but there is, we understand, a proposal under consideration to re-establish it.

§Either Deccan trap or Phyllites or Schists or Conglomerates.

‖The link can be taken from Gurra railway station or, preferably, from the Belawara railway station, if it is going to be re-established.

northern grid so that "a hydro-thermal balance" can be provided and the water in the reservoir can be utilised "to the fullest extent possible". The arrangement will probably mean somewhat cheaper power for the factory than power from a completely independent thermal station. The Tawa dam would be useful in ensuring continuous supply* of whatever water may be required for factory purposes; and the supply would be plentiful enough to obviate cooling and recirculation arrangements. Even before the execution of the Tawa project, the required make-up water would be available from the Tawa river which, like the Narmada, is a perennial stream fed from the Satpura springs. We have been favoured with a statement of average daily and monthly flow in the Tawa river at the dam site month by month from July 1948 to December 1952 and we gather from it that the recorded minimum flow in the river in April 1951 (1952?) was 27 cusecs which is well above the anticipated daily requirement of a fair-sized fertilizer factory. We are satisfied on the evidence before us and also after our personal inspection towards the end of May that supply of water for a factory located at the proposed site would not present any serious problem though it would be advisable, in order to make water supply completely secure pending the approval and execution of the Tawa project, to take certain special measures by way of, for example, the construction of a barrage or anicut and/or provision of metal or concrete strainers in the bed of the river.

Of the two main raw materials required, namely gypsum and coal, it is proposed to obtain the latter from the Tawa Valley coal seams about 50 miles away from the suggested location of the factory. Having considered the available reports on these deposits which have been extensively reproduced in the Madhya Pradesh memorandum, we are satisfied that the coal reserves are sufficient; in any case, they are in continuation of the more extensive deposits in Pench and Kanhan valleys. The exploitation of Tawa coal at Pathakhera would involve the construction of a short rail link of about 10 miles to connect the coal fields with Ghoradoongri railway station. The Pathakhera coal occurs in three seasons of which the top seam is reported to be of poor quality while the middle and bottom seams are of fair quality and, in any case, suitable for ammonia synthesis. The coal is non-coking with 26 per cent ash, 45 per cent fixed carbon, and 27 per cent volatile matter.

It is assumed that the other raw material, gypsum, for making ammonium sulphate or sulphate-nitrate would be imported from Rajasthan, preferably Jodhpur which is nearer. The distance between Kavas in Jodhpur and Itarsi is about 700 miles and between Jamsar in Bikaner and Itarsi is 800 miles. These distances compare favourably with the distances between Sindri on one hand and Kavas and Jamsar on the other hand which are, respectively, 1,125 and 1,050 miles.

The other advantages claimed in favour of the location are:

(i) Itarsi is very nearly in the centre of India and therefore an ideal site from the distribution point of view. Rail com-

*The reservoir would, however, be a few miles upstream in relation to the factory site; therefore a special channel or conduit would be necessary for supplying water to the factory. According to present plans, the main irrigation canal from the Tawa reservoir would run very close to the northern boundary of the factory site.

munications are excellent, Itarsi being a junction of the main trunk connecting Bombay with Calcutta and Delhi with Madras. Katni cement, only 150 miles away, would be available for building purposes.

(ii) The Madhya Pradesh Government have a scheme for the production of soft coke to replace current use of charcoal which costs at present as much as Rs. 5 per maund. When the soft coke scheme goes through, expansion of any fertiliser factory which may now be put up would be possible with the help of the gas available from the soft coke plant. In fact, we were given to understand in discussion that should a provisional decision be taken to locate a fertiliser factory in the Itarsi region, the planning and execution of the soft coke scheme would probably be synchronised with the fertiliser factory scheme.

The location suggested by the State Government has without question such advantages as to justify their full investigation. We have accordingly calculated production costs of ammonium sulphate/double salt and urea at the suggested location on the following basis:

(i) synthetic ammonia will be made directly by gasification of Tawa Valley coal of which we have taken the price, delivered at site, to be Rs. 20 per ton;

(ii) we have included in the capital cost a reasonable sum* on account of the special measures that it may be necessary to take to ensure complete safety of water supply pending the construction of the Tawa dam;

(iii) we have, similarly, provided for railway extensions from Kiratpur on the Delhi—Madras line to the factory site and also from Ghoradoongri on the same line to the coal fields at Pathakhera, but not, at this stage, for the short rail link to connect the factory site with the Bombay—Calcutta line;

(iv) we have assumed that the factory will have its own independent thermal power station and will produce sufficient power for factory and its associated township; and

(v) we have assumed utilisation of Rajasthan gypsum partly from Jodhpur and partly from Bikaner.

We would mention in the end that we have considered, but have been unable to accept, another location in Madhya Pradesh which was commended to our attention by the Railway authorities. It was suggested by them that a very suitable location for one of the new production units may be the point where the new metre gauge link connecting Khandwa in Madhya Pradesh with Hingoli in Hyderabad, which is already under construction, cuts the broad gauge line

*We have provided for a sum of Rs. 90 lakhs on this account, inclusive of pumping installations. In view of the difficult nature of the terrain, the actual investment may be appreciably larger and may amount to as much as a crore and half of rupees if a factory located at this site has ultimately to arrange for its own independent water-supply installations.

on the Nagpur—Bhusaval section near Akola. The location would undoubtedly be almost ideal from the transportation point of view since it will have the advantage of being served by both metre gauge and broad gauge systems and consequently no break-of-gauge transhipment would be required for transportation of either raw materials like gypsum or coal or the end-products. On the other hand, both coal and gypsum would be farther away from Akola than from Itarsi. The nearest coal in the Wardha coalfields would be about 190 miles away from Akola by rail while Pench valley coal would be nearly 300 miles away by the circuitous rail route. Compared with Itarsi, Akola will have to reckon with an *extra* distance of about 40 miles in regard to gypsum and 135 miles in regard to coal. We apprehend further, that the problem of water supply will be difficult of solution. unless the factory is sited at Chandni 30 miles south of Khandwa junction and advantage is taken of the Tapti reservoir there. This would, however, involve the construction of a short metre gauge siding to establish connection with the new Khandwa-Hingoli metre gauge link; but even then the difficulty about longer haulage for coal and gypsum would remain. Since it is fairly clear that the economics of the Akola location would stand no comparison with those of the Itarsi site, we have considered it unnecessary to investigate its potentialities in detail despite its obvious advantages from the point of view of railway transportation. The State Government of Madhya Pradesh whom we have consulted fully concurs in our view of the matter.

(xiii) VINDHYA PRADESH

The State Government's suggestion is that a factory may suitably be located at Burhar or Annuppur on the Eastern Railway in Shahdol district for the production of ammonium sulphate/ammonium nitrate/sulphate-nitrate along with urea. There are extensive coalfields in the immediate vicinity of the suggested location which is certainly a considerable advantage from the point of view of economic production of urea and ammonium nitrate for which the principal raw material is coal. As regards gypsum or sulphur for the manufacture of ammonium sulphate, a reference has been made to gypsum occurrences in certain villages close to Annuppur railway station. Alternatively, it has been suggested that sulphur should be recovered from local coals which are reported to contain appreciable quantities of iron pyrites. It is said that "if the coal is washed at 1.58 sp. gr. and the rejects beneficiated, theoretically nearly 1.6 tons of pyrite (about 0.8 tons of sulphur) could be recovered from 100 tons of coal". On this basis it is concluded that about 48 tons of pyrites or 24 tons of sulphur can be recovered per day by washing and beneficiating 3,000 tons of coal.

Even though proximity of the suggested location to extensive coal deposits is an indication of the possibility of economic production of nitrogenous fertilisers, we have not investigated the State Government's proposal in any detail for the following reasons:

(a) Since the end-products to be established must be ammonium sulphate and/or sulphate-nitrate and urea in accordance with our terms of reference, nearness to sources of supply of sulphur or gypsum is an important factor. The reported gypsum deposits in the district of Shahdol have not admittedly been prospected as yet; and nothing definite can, therefore, be said about the quality of the material or, what

is more important, the extent of the deposits. Considering that Vindhya Pradesh gypsum is not even mentioned in any of the reports of the Geological Survey of India, we have to conclude, pending further investigation, that the gypsum occurrences that have come to notice are probably sporadic in nature and, in any case, not of any great practical significance. We do not consider also that the recovery of pyritic sulphur from Vindhya Pradesh coals by washing and beneficiation is a practicable proposition. Not only would an elaborate plant have to be installed for washing and beneficiating coals on a large scale, but a market will have to be found for the very considerable quantities of coal after sulphur has been recovered from it. We are inclined to doubt, indeed, whether the sulphur content of Vindhya Pradesh coals is high enough to justify the expectation that its economic recovery is a reasonable possibility.

(b) We are thus forced to conclude that if sulphate-nitrate has to be produced at the suggested location it will be necessary either to import sulphur from abroad or bring gypsum from Rajputana. Import of sulphur is obviously not a feasible plan as Vindhya Pradesh is far away from any sea port and inland transportation costs are heavy. On the other hand, if Rajputana gypsum has to be utilised, more economical production of the end-product can be ensured by locating the factory at a place near the coal deposits farther to the west in the Satpura basin in Madhya Pradesh. Considering the situation of Sindri and Nangal, such a location should have preference from the point of view of proximity of consumer points also.

(xiv) HYDERABAD

In discussion with the Committee the Government of Hyderabad have suggested two alternative locations for a fertiliser factory, namely,

(a) at Kothegudium or Bhadrachelam Road on the border of the Singareni coal fields and

(b) at Ramagundam, about 20 to 25 miles away from the Belampalli or Tandur collieries.

Both the suggested locations are well served by road and rail communications. Ramagundam is a railway station on the Chanda-Warangal section of the main Nagpur—Chanda—Warangal—Vijayawada line. A branch line has been taken to Kothegudium (Bhadrachelam Road) from Dornakal railway station on the Warangal—Vijayawada section of the same Trunk Line.

Both locations are on the Godavari, Kothegudium being 150 miles from the sea port at Kakinada and Ramagundam being about another 150 miles higher up. The proximity of both the locations to the Godavari, which is a perennial river, would ensure continuous supply of sufficient water at either location. We estimated, after local investigation, that the minimum flow in the Godavari is about 200 cusecs in the driest month near Ramagundam and over a thousand cusecs near Kothegudium.

A factory at Kothegudium would be able to use either high grade (17 per cent ash) or low grade (33 per cent ash) coal; on the other hand, a factory at Ramagundam would have to utilise high grade coal which alone is being currently exploited in the Tandur collieries. The coal reserves at either place are sufficient to warrant the location of a fertiliser production unit. The collieries are to a very large extent State-owned (the Hyderabad Government owning 90 per cent shares in both the Singareni and the Tandur coal fields), but perhaps largely because of this fact, coal at either place is somewhat *expensive, the pithead price of run-of-mine coal being Rs. 22 per ton. The difference between the prices of high ash and low ash coal in the Singareni coal fields is only Re. 1 per ton.

Because of proximity to extensive coal reserves and a perennial stream either location is suitable for a nitrogen fixation factory, but their potentialities are not entirely identical as explained in the next two sub-paragraphs.

(1) A factory located on the border of the Singareni coal fields at Kothegudium will be at a disadvantage in regard to its distance from deposits of indigenous gypsum. On the other hand, it is possible to utilise imported sulphur or pyrites or gypsum which can be conveniently brought to the site by sea and river route *via* the Kakinada port†

Alternative sites are available at Kothegudium for location of a factory at varying distances from coal reserves and the river. The choice of a site on the fringe of the coal fields and within 3 miles from the railway line will involve somewhat special arrangements for water supply by way of construction of a dam across one of the two local tributaries of the Godavari, the Mureru or the Kinarsani, which

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*We attempted to find out the reasons why Singareni coal should be so markedly dearer than coal in Bengal—Bihar and concluded that this is due to a number of factors, the chief of which are relatively high labour wages, difficult mining conditions, absence of sufficient railway sidings and provision of amenities for miners and colliery workers on a very generous scale; for example, 100 per cent housing and medical aid is the rule in Singareni coal fields.

†We gathered during our local investigations that power launches up to 100 tons capacity usually ply between Bhadrachalam (which is situated on the left bank of the Godavari just opposite one of the sites suggested at Kothegudium) and Rajahmundry from July to the end of December. In January, launches of smaller capacity, that is, upto 40 tons only, can come up to Bhadrachalam. In February and March only country craft of 20 tons capacity can come to Bhadrachalam but launches upto 40 tons capacity can ply between Rajahmundry and Koonavaram which is thirty miles down-stream of Bhadrachalam, just below the confluence of the Godavari and its tributary, the Saveri. In April, May and June the river is navigable between Rajahmundry and Inpur which is 42 miles down-stream of Bhadrachalam. A navigation channel 40 miles long connects the Dhavleshwaram anicut at Rajahmundry with Kakinada port. The canal is navigable from July to February and is usually closed for silt removal and repairs from March till the end of June. The net conclusion thus is that for at least half the year imports can be brought without much difficulty by the sea route *via* the Kakinada port along with Kakinada-Rajahmundry canal and the Godavari river right up to Bhadrachalam.

would certainly cost at least half a crore of rupees. It would be possible to bring water from the reservoir so created to the factory site by gravity. On the other hand, one or more alternative sites are available close to the Godavari at a safe level but then coal would have to be transported over a distance of 16 miles or so and a rail link will have to be provided covering about 12 miles. A factor that will have to be taken into account in case a factory is located in the neighbourhood of Kothegudium is the water spread of the proposed Rampadasagar Dam. The building of this dam has been under consideration for some years but we understood, while we were at Kurnool, that the proposal has now taken a definite shape and the siting of the dam had been finalised at a point on the Godavari about 30 miles downstream of Bhadrachalam. The water spread would not, however, reach 200 ft. above mean sea level in view of which the particular sites suggested by the Hyderabad Government near about Kothegudium seem to be all feasible.

Kothegudium has a well-developed township stretching for miles into the heart of deep jungle where new inclines of shafts are still being sunk to exploit virgin deposits. The township includes, among other amenities, a 200 bedded well-equipped and well-staffed hospital, welfare centres, creches, schools, markets, a cinema house, clubs for officers and workers, permanent tenements for all wage-earners down to the lowest level, etc. etc. A new thermal plant of 17,500 K.W. capacity is nearing completion.

The price of land in the locality is low since practically all lands in the neighbourhood are forest area, mostly owned by Government. The average price of land can safely be taken to be not more than Rs. 300 per acre.

(2) Ramagundam is on the right bank of the Godavari while the Tandur collieries are 20 to 25 miles away across the river. On the left bank of the Godavari just opposite Ramagundam is Mancheral where there is an A.C.C. cement factory. The main reason why Ramagundam instead of Mancheral (which would be nearer the coal fields) has been suggested for the location of a fertiliser factory is the fact that the Hyderabad Government have taken in hand the construction of a large power plant at Ramagundam, mainly as a matter of general development of the area. The installed capacity of the plant will, for the time being, be 37,500 K.W. but with boiler capacity for a maximum load of 25 MW for the present. Room has been reserved for not only additional boilers but also 2 more turbines each of 15,000 K.W. capacity*. The cost of generation of power is likely to work out to, we understood, about 1 anna per unit, but contracts have already been entered into for supply of power to industrial units like A.C.C. cement factory at Mancheral on the other side of the river at 9 pies per unit; and we were assured that power would be available for the fertiliser factory at the same rate. The cost of Belampalli or Tandur coal delivered at the power plant site comes to just over Rs. 25 per ton inclusive of railway freight and loading, unloading, and handling charges.

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*It will, we understand, be possible to install two 30 M.W. sets (instead of two 15 M.W. sets) provided certain modifications are made in the foundations.

A fairly good workshop with reasonable fabrication and repair facilities is attached to the Power Plant. Technicians are obtained from one or other of the three main technical training institute* in Hyderabad city. Along with the power house a colony complete with civic amenities is being built at an estimated cost of over Rs. 4 crores. Since permanent houses are being built for the entire construction staff, about 50 per cent of the colony will be vacant when the power plant goes into operation.

Ramagundam would be an ideal site for a nitro-limestone plant since limestone hills occur on both sides of the river, though the better quality deposits are on the Mancheral side on the left bank. For the manufacture, however, of ammonium sulphate or sulphate-nitrate, it would be necessary to bring gypsum from Rajasthan.

The river is 3 miles away from the power house as a crow flies. The power plant management is sinking a semi-circular well on the river bed along with cement concrete strainers, laid 15 ft. below the sand, for a length of 500 ft. from the well across the river. The chain of concrete strainers will function as an infiltration gallery for tapping underground water. The bottom of the well would be 50 ft. below the river bed level where pumps are being installed with a capacity of 1½ million gallons per day plus an equivalent spare capacity. It is interesting to note that the entire job has been entrusted to a Hyderabad Engineering firm. Space is being reserved for the installation of three additional pumps (of any desired capacity) in the expectation that one of the new fertiliser units (or some other factories) will be located at Ramagundam. A new pipe line will have, however, to be laid in that case for bringing the water from the well to the factory site. A three-miles long metalled road is under construction to connect the Power Plant with the well on the river bed. Taking into account the capital investment in the water works and other factors, the management has costed water delivered at the plant at -/2/- per thousand gallons.

Should it be decided to locate a fertilizer factory at Ramagundam, its siting will require careful consideration, particularly if it is intended that it should get its supply of process steam from the power plant. The power plant itself has been sited on what appears to be an old bed of the Godavari but firmer land on a higher level is available in its immediate vicinity. Land is cheap and we understood that 9000 acres have been acquired for the power plant and its attached colony at rates varying between Rs. 50 and Rs. 200 per acre, the average rate being Rs. 75 per acre. Only 250 acres out of the total acquired area is being utilised at present.

Since both the locations at Kothegudium and Ramagundam have definite possibilities from the point of view of economic production of chemical fertilizers, we have taken both of them into consideration for purposes of assessment of production and distribution economies.

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* Supervisory personnel can be trained at the Government Technical College and the Civil Sub-Overseers' Training Centre at Hyderabad and skilled craftsmen at the Central Crafts Institute. There are, besides, eight Technical High Schools at different places in the State.

(xv) BOMBAY

The specific proposal we have received from the State Government is that advantage should be taken of the cheap and abundant electricity likely to be available after the execution of the Koyna project, to manufacture at Karad in North Satara district a suitable type of nitrogenous fertiliser. The Koyna* dam is sited near Helwak on the eastern slopes of the continental divide on the Western Ghats about 200 miles away by rail and road from the city of Bombay. As at present planned, the Koyna project is a purely power generation scheme since the spill water would flow down the western slopes of the continental divide into the Arabian sea and would not thus be available for irrigation purposes. In the first stage of the project it is proposed to instal four generators each of 60,000 K.W. capacity. The installation is expected to be completed by 1960-61 and full power from all the four generators would, we were told, be available sometime towards the end of 1961 or beginning of 1962. According to present load forecasts, at least 100,000 K.W. would, it is said, be available for a fertiliser factory by the end of 1961 or beginning of 1962, from the inter-connected thermal *cum* hydro-electric system. We have been assured that the cost of Koyna power would be 0.25 anna at the point of generation. At Karad, which is the suggested location for a new fertiliser factory, 50 miles away from the site of the Koyna project, the cost of energy would be 0.3 anna† to which some addition will have to be made on account of State Electricity Tax.

Karad is well served by trunk road communications and is a railway station on the Poona-Belgaum section of the old Madras and South Mahratta metre gauge Railway. It is situated at the confluence of the Koyna and the Krishna; and for water supply it is proposed to depend on the Krishna reservoir which is within a mile or so of the site provisionally selected for a fertiliser factory. There is at this point a 70 year old weir on the Krishna, built purely for irrigation purposes, just before the Krishna joins the Koyna. We were told during our visit that the minimum flow in the Krishna in the driest month (May) is 18 cusecs below the weir, in addition to which there is, of course, the storage capacity of the reservoir. On the whole, we think that should a factory be located at the suggested site, no special measures of expensive arrangements would be necessary to ensure the security of its water supply. Land values at Karad are relatively low and, we understood from the Collector of North Satara, vary between Rs. 300 and Rs. 500 per acre.

The State Government's suggestion is that the available power of the order of 100,000 K.W. should be utilised to produce ammonia by electrolytic decomposition of water and liquefaction of air. If the end product to be established is ammonium sulphate or double salt, it is proposed to import sulphur via Bombay port involving inland transportation (Bombay-Karad) over a distance of more than 200 miles. Utilisation of gypsum will not be possible because carbon dioxide will not be available as a co-product in the manufacture of ammonia by the electrolytic process. For the same reason, urea production will not be possible unless carbon dioxide is specially

*The dam will be about 260 feet high and 2,000—2,500 feet wide. The capacity of the reservoir will be 30,000 million cu. ft.

†We have been assured by the State Government that inclusive of the State Electricity Tax, Koyna power would be available for a fertiliser factory at Karad at a rate not exceeding 0.32 anna.

arranged for by burning limestone which, however, will be expensive and render the production of urea or ammonium sulphate (by the gypsum process) uneconomic. As an alternative to ammonium sulphate, it has been suggested that the end product may be either pure ammonium nitrate or calcium nitrate/nitro-chalk, the required limestone being brought from Bagalkot in the Bijapur-Shahabad region. The *distance by rail from Bagalkot to Karad is 314 miles.

We are unable to say that we have found many attractive features in the State Government's proposal which, we note, has been endorsed in the memoranda we have received from the Maratha Chamber of Commerce of Poona and the Maharashtra Chamber of Commerce of Bombay (Appendix II). In the first place, the cost of Koyna hydro-electric power at Karad would be hardly low enough for economic production of ammonia by the electrolytic process in a †50,000 tons/year nitrogen fixation plant. Secondly, the power will not, in any case, be available till about the end of 1961 or beginning of 1962 which is far too late for the present expansion programme. Thirdly, we do not consider that to make either ammonium sulphate or double salt by importing sulphur *via* Bombay involving a railway haul of over 200 miles is, economically, a feasible proposition. Again, if limestone has to be brought by railway over a distance of more than 300 miles, there is little hope of establishing economic production of even nitro-chalk or calcium nitrate apart from the fact that these fertilisers are, in any case, outside our terms of reference. We have not, for these reasons, considered it necessary to investigate the potentialities of Karad in detail. We note, however, that according to the rough calculations we have made, the cost of production of ammonia (by electrolytic process) and sulphate-nitrate at Karad in a 50,000 tons/year nitrogen plant, would amount to about Rs. 477 and Rs. 277 per ton respectively on the assumption that the cost of power will not exceed 0.32 of an anna per unit and the cost of raw water will be 8 annas per thousand gallons. These ‡estimates compare unfavourably with the production costs of ammonia and double salt at any of the locations provisionally selected by us for fuller investigation.

Independently of the State Government's specific proposal we have investigated the possibility of utilising spare gases from the newly installed refineries at Trombay for production of the specified types of nitrogenous fertilisers. We refer in this connection to the facts we have explained and the conclusions we have reached on this subject in Chapter III. It has not been possible for us to pursue our investigations to a stage where we could definitely establish the

*The distance, as a crow flies, is only 125 miles.

†This will be the capacity of the plant (250,000 tons a year in terms of ammonium sulphate), assuming availability of 100,000 K.W. of hydro-electric power.

‡It would indeed be much cheaper to make ammonia at Karad by gasification of coal or coke brought all the way from Bihar/Madhya Pradesh assuming of course simultaneous utilisation of cheap hydro-electric power for normal factory operations. Our estimated cost of production of ammonia (by the electrolytic process) would then come down by nearly Rs. 120 per ton in a 50,000 tons/year nitrogen plant. We have not seriously considered this alternative having regard to the great transportation difficulties which such an arrangement would involve and the other reasons we have mentioned above, particularly the fact that hydro-electric power would not be available till the end of 1961 or beginning of 1962.

availability of a minimum quantity of gas for a State-owned fertiliser production unit from Burmah-Shell refinery; nor has it been possible for us to negotiate a fair price for the 2.3 m.cu.ft. of gas that will be available from the Stanvac refinery. As a result of our studies, however, we have come to the conclusion that even if no more than 2.3 m.cu.ft. of gas is ultimately *available, it would still be possible to locate, quite advantageously, a nitrogen fixation factory in the neighbourhood of Trombay refineries, provided the gas can be secured at the price which we have indicated as fair and reasonable.

We understood that a fairly extensive area around Trombay is already under notification under the Land Acquisition Act out of which an area sufficient for the installation of a fertiliser factory is likely to be available without much difficulty. The average price of land in the locality is, we understand, Rs. 10,000 per acre. We have further ascertained that the Bombay Municipality would be in a position to make available after 1958 a certain quantity of fresh water for factory purposes up to 8 million gallons per day. Supply of fresh water to this extent would be required for a relatively large nitrogen factory particularly since sea water would not be of much use in it. The cost of municipal water would, we understand, be around Re. 1 per †thousand gallons. On the basis of the above data, and assuming that electricity for industrial purposes would be available at 0.55 anna per unit upto the required ‡extent, we have provisionally calculated likely production costs of the specified fertilisers at a factory located in the neighbourhood of Trombay, utilisation of Saurashtra gypsum being presumed for the manufacture of ammonium sulphate/sulphate-nitrate.

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* We understand from the Bombay Government that if this Committee recommend the location of a fertiliser plant at Bombay for the utilisation of cheap waste gases from the two refineries, "the Bombay Government may try to persuade the Burmah-Shell to give their gas for the proposed plant.

† We understand from the Bombay Government that "If the factory is going to be a Government Department, the rate charged would be about 14 annas per thousand gallons, but in case the factory is to be run by a statutory Corporation, the rate for water would be somewhat higher and it will have to be negotiated." Even if water has to be paid for ultimately at a somewhat higher rate than Re. 1 per 1,000 gallons, economic production of the specified fertilisers would still be possible if our other assumptions materialize.

‡We understand that provided a demand is registered within the next 6 or 7 months, about 30,000 K.W. will be available by 1958-59. To quote from a letter dated the 20th April, from the Government of Bombay: "A fertiliser factory, if established at Trombay, may have to pay for electricity power at 0.55 of an anna per unit inclusive of Electricity Tax. But with the use of waste gases from the Refinery, the quantum of electrical energy would be much less, i.e. by (?) about 30,000 to 40,000 K.W. There is a possibility of getting the electrical energy at Trombay from the Trombay Plant which the Tatas are putting up at present. The first unit is expected to function from September 1956, and the other a year later." In a later letter dated the 28th April the Bombay Government have confirmed that "the rate now given of .55 anna is the correct one unless there is an increase or decrease in the rate in future. This increase or decrease is likely to be very small. After the second Tata plant comes into operation, which, we hope, will be October 1957, we do not think there will be difficulty in allotting this quantity of electricity (30,000 to 40,000 Kilowatts), particularly if an early booking is made."

(xvi) *SAURASHTRA

With the help of an expert committee the Saurashtra Government has prepared a very carefully got up and well-documented memorandum making out a case for the establishment of an ammonium sulphate factory at Sikka port on the gulf of Kutch. Sikka is an all-weather port conveniently situated in a creek having a deep channel, about 600 yards wide, 3 miles from the high water line. There is a cement factory at Sikka of 200,000 tons/year capacity which is likely to be doubled in the near future. Messrs. Digvijay Cement Company Ltd. who own the factory are building a rope-way 3 miles long right into the creek up to the deep channel to .acilitate direct loading of cement in large sea-going steamers.

Sikka is connected with the main Rajkot-Jamnagar-Khambatia-Dwarka-Okha railway line by a branch line which takes off from Kanalus railway station. It is also connected by a metalled road with Jamnagar. The entire railway system inside Saurashtra proper is on the metre gauge and therefore for incoming raw materials or outgoing products by the land route, transhipment from metre gauge to broad gauge or *vice versa* is involved.

It is proposed that gypsum for manufacture of ammonium sulphate should be obtained from the gypsum deposits in the neighbourhood of Bhatia railway station about 50 miles away from Sikka. We have discussed the gypsum deposits in Saurashtra in Chapter III; it would suffice to note here, that Saurashtra Government's estimate of a reserve of 6½ million tons of gypsum in Kutch and Saurashtra is realistic and the analytical data furnished in respect of the variety of gypsum found there are accurate. Although we are a little doubtful about their estimate of cost of winning gypsum using modern upto date machinery, we provisionally accept their conclusion that the cost of gypsum delivered at Sikka by rail would be in the neighbourhood of Rs. 16 per ton.

With regard to the other important raw material, coal, the suggestion is that good coking coal should be brought by rail from the Bihar coal fields to Sikka and locally coked. We understood that the cement factory at Sikka is getting grade IIB coal from Bihar at a cost of Rs. 52 per ton inclusive of freight and handling charges. A part of the coke, it is suggested, should be used to produce synthesis gas as at Sindri and the rest of the coke including coke breeze should be sold to meet local requirements of Soda Ash factories, foundries, and cement factories. It is proposed to use the coke oven gas for steam and power generation.

Whether this is the most economical method of utilising expensive coal brought from Bihar coal-fields is open to doubt but what

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*With their letter dated the 9th May 1955, the Government of Saurashtra sent us a supplementary memorandum which, we regret, we have had no time to examine in detail. We note, however, that there is nothing in the supplementary memorandum which would justify any revision of our view that production economics of a plant located at Sikka should be calculated on the basis of utilisation of Saurashtra gypsum and Bihar/Madhya Pradesh coal. In particular, we take the view that it would be altogether inexpedient for a State-owned fertiliser factory to get itself involved in a scheme which visualises large-scale production of coke for sale to local consumers at a competitive price.

is clear is that coal will have to be brought from outside for manufacture of synthesis gas. The nearest coal fields are in Madhya Pradesh and we understood that Madhya Pradesh coal delivered at Sikka costs Rs. 32 per ton inclusive of a freight element of Rs. 14 per ton.

There is a State-owned power plant at Sikka which is operated on pulverised coal with an installed capacity of 8,000 K.W. The power station supplies power to the cement factory, and it is suggested in the Saurashtra memorandum that in the event of an ammonium sulphate factory being located at Sikka, the power house could be suitably expanded to take the increased load and supply not only power but also process steam to the fertiliser factory. Whether, again, this is a more feasible plan than the installation of an independent thermal power station as an integral part of the fertiliser factory is a question which would require careful examination.

While any quantity of sea water will be easily available for limited purposes, supply of a minimum quantity of fresh water is a problem of which the suggested solution is that the entire requirement should be drawn from two nearby irrigation reservoirs recently created by damming up the Puna and the Sosoi rivers. The reservoirs are located about 8 miles away from Sikka and their total capacity is 2300 million cu.ft. of water. It is suggested that water from the two reservoirs should first be pumped to a factory reservoir on comparatively high ground and then brought by gravity to the factory site. We note that the cement factory gets its relatively small supply of 200,000 gallons of fresh water a day from wells sunk on the bed of the Sosoi downstream of the dam recently constructed on it.

In the Saurashtra memorandum detailed cost calculations have been furnished to establish that with a 230 tons/day ammonium sulphate factory the cost per ton of the finished product would be Rs. 250 and for a 500 tons/day production unit, it would be Rs. 214. The calculations have been made on the assumption that ammonia would be made by the semi-water gas process from coke locally made from imported Bihar coal, the factory utilising local gypsum and having its own arrangements for steam and power generation.

Considering all factors, we have taken the view that the potentialities of locating one of the new fertiliser units at Sikka require detailed investigation.

4. On reviewing the State Governments' proposals, we have thus selected eleven locations for further study. For the selection of two of these locations we have had to rely on provisional data. In the case of Bombay, there is still no certainty of supply of any portion of the Burmah-Shell refinery gas; and even in regard to the 2.3 million cu. ft. of Stanvac gas, the availability of which is assured, our recommendation for its utilisation is conditional on the negotiation of a fair price for it. Similarly, in the case of Neyveli, the assumed economies based on Powell Duffryn estimates are at present uncertain and tentative and must await confirmation or correction in the light of the results of the experiments and studies that are now in hand. In these two cases we had to choose between the alternatives of (i) ruling out the locations altogether on the score of lack of definitely verified and established data; and (ii) taking them into account along with other suitable locations on a provisional basis subject to reservations. We

have thought it expedient to decide in favour of the latter alternative since the two locations are among the most promising of those we have had occasion to consider. Our decision, however, involves the consequence that any comparison of the economic and other advantages, of the two locations with those of other locations must be regarded as conditional; and to the extent that our final recommendations may be in their favour, those recommendations must also be deemed to be conditional.

5. We can now conveniently summarise the results of our study of the State Governments' proposals in the tabular statement below which shows at a glance the locations whose potentialities, we think, need closer examination. The table indicates also the sources of the raw materials which, in the light of the conclusions we have reached in Chapter III, can, in our view, be most suitably processed at each individual location for the manufacture of the end-products to which our choice is restricted by our terms of reference, that is, ammonium sulphate, double salt and urea apart from ammonium nitrate at Nangal. Nangal has not been included in the table since a definite decision has already been taken to instal a nitrogen fixation plant there. It will no doubt be noticed that we have not entirely restricted our consideration to only those locations which have been commended to our attention by the State Governments. We have independently considered a number of promising locations and, in particular, have taken full account of the potentialities, from the point of view of production of fertilisers, of the various hydro-electric and multi-purpose river valley schemes approved for the first five-year plan or under consideration for the second five-year plan. Three of the eleven locations provisionally chosen by us for detailed study (Sawai Madhopur in Rajasthan, Trombay in Bombay and Hathras in Uttar Pradesh) are thus in a sense our independent selections.

TABLE

Location	Raw materials and their sources	Nearest port for imports
1. Neyveli (Madras) .. .. Lat. 10°—55′ Long. 80°—30′	(a) South Arcot lignite (b) Trichinopoly gypsum.	Cuddalore.
2. Vijayawada (Andhra) .. .. Lat. 16°—30′ Long. 80°—35′	(a) Singareni coal (b) Rajasthan & Trichinopoly gypsum.	Masulipatam.
3. Durgapur (West Bengal) .. Lat. 23°—30′ Long. 87°—20′	(a) Ondal-Raniganj coal or coke oven gas (if and when available). (b) Rajasthan gypsum	Calcutta.
4. Hathras (Uttar Pradesh) .. Lat. 27°—35′ Long. 78°—00′	(a) Bihar coal (b) Rajasthan gypsum	

Location	Raw materials and their sources	Nearest port for imports
5. Hanumangarh (Rajasthan) .. Lat. 29°—35′ Long. 74°—15′	(a) Palana lignite (b) Rajasthan gypsum	
6. Sawai Madhopur (Rajasthan) .. Lat. 26°—00′ Long. 76°—20′	(a) Madhya Pradesh coal (b) Rajasthan gypsum	
7. Itarsi (Madhya Pradesh) .. Lat. 22°—40′ Long. 77°—25′	(a) Pench Valley coal (b) Rajasthan gypsum	
8. Kothagudium (Hyderabad) .. Lat. 17°—10′ Long. 80°—10′	(a) Singareni coal (b) Rajasthan/Trichinopoly gypsum.	Kakinada.
9. Ramagundam (Hyderabad) .. Lat. 18°—45′ Long. 79°—25′	(a) Tandur—Belampalli coal (b) Rajasthan gypsum	
10. Trombay (Bombay) .. .. Lat. 19°—00′ Long. 82°—55′	(a) Refinery gas (b) Saurashtra gypsum	Bombay.
11. Sikka (Saurashtra) .. .. Lat. 22°—25′ Long. 69°—50′	(a) Madhya Pradesh/Bihar coal (b) Saurashtra gypsum	Sikka.

CHAPTER V—PRODUCTION UNITS—NUMBER AND LOCATION

SECTION I—CONSIDERATIONS RELEVANT TO DETERMINATION OF PLANT CAPACITY AND NUMBER OF PRODUCTION UNITS

We have considered it convenient to deal with the question of processes with reference to the finally selected locations for the new production units. We would like to state, however, in anticipation, since the matter has an important bearing both on the determination of plant capacity and selection of suitable locations, that it would, in our view be inexpedient to establish an independent urea production unit under the present expansion programme. We *recommend that in the present stage of our progress in the field of practical chemical engineering, the establishment of an urea production unit should be associated with an ammonium sulphate or an ammonium nitrate plant so that the advantages of the "once through" process may be secured and it is possible to avoid recycling, a complicated operation of which the attendant problems have not yet, to our knowledge, been completely satisfactorily solved anywhere. We refer in this connection to the views of the Indian Fertilizer Mission in para 27(b) Chapter III of its report which we endorse.

2. As a result of the review made in the previous Chapter IV we have concluded that solely from the angle of production economies, the potentialities of 11 locations deserve critical and close study. Before setting out the results of this study it would, we think, be useful to examine, on certain *a priori* assumptions, the question as to the number of units in which a total production of †100,000 tons of nitrogen can be economically arranged. A similar issue was considered by the Technical Mission appointed by Government in 1944 and we refer to the conclusions arrived at by that Mission in paragraphs 77—86 of its report.

3. Assuming identical production conditions, in other words, identical investments, identical costs of raw materials and utilities and identical wage bills, our examination has led us to conclude, subject to the reservations we explain below, that the *minimum* capacity of an economic fertiliser production unit should be of the following order for different products:

TABLE 1

Product	*Minimum capacity of an economic unit*
(1) Ammonia ...	... 60,000 tons of ammonia or roughly 50,000 tons of nitrogen per year.
(2) Ammonium nitrate	... 145,000 tons of pure ammonium nitrate or roughly 50,000 tons of nitrogen per year.

*Please also see in the same connection, para 12(d) of Chapter II.

†Excluding 70,000 tons which it has been decided to produce at Nangal.

TABLE 1—*contd.*

Product	*Minimum capacity of an economic unit*
(3) Ammonium sulphate ...	250,000 tons of ammonium sulphate or roughly 50,000 tons of nitrogen per year.
(4) Double Salt	250,000 tons of sulphate-nitrate or roughly 65,000 tons of nitrogen per year.
(5) Urea*	50,000 tons of urea or roughly 22,500 tons of nitrogen per year.

For the data on which these conclusions are based we refer to the statements illustrated by graphs in Annexure VI. The graphs will indicate at a glance that till the critical level of production which we have indicated as "economic" is reached, production costs continue to come down fairly steeply as the production unit becomes larger; but once the "critical level" is reached, the economic advantage starts to taper off gradually until a state of near-stability is attained at varying points for various types of products. The point of near-stability is the point where the maximum production economy is attained and it thus indicates in a sense the optimum size of production units. The graphs in Annexure VI will show that the optimum production capacity in this sense is as follows for different products:

TABLE II

Product	*Optimum capacity*
(1) Ammonia	100,000 tons of ammonia or 82,300 tons of nitrogen per year.
(2) Ammonium nitrate ...	200,000 tons of pure ammonium nitrate or 70,000 tons of nitrogen per year.
(3) Ammonium sulphate ...	350,000 tons of ammonium sulphate or 70,000 tons of nitrogen per year.
(4) Double Salt	350,000 tons of sulphate-nitrate or 90,000 tons of nitrogen per year.
(5) Urea	110,000 tons of urea or roughly 50,000 tons of nitrogen per year.

A further useful conclusion that can be drawn from the statements and graphs in Annexure VI is that in regard to the five products under discussion the production units would be, not

*Assuming that the basic raw material, ammonia, will be produced in a 60,000 tons/year ammonia plant, whatever may be the size of the urea production unit. In the other three cases, the assumption is that the production of ammonia and the end product will go together i.e. that ammonium nitrate or ammonium sulphate or double salt will be made from ammonia manufactured in *a plant of corresponding size*. The same assumptions have been made in Tables II and III (A).

merely relatively, but absolutely uneconomic if they are below the capacities indicated in the following table·

TABLE III(A)

Product	*Capacity below which production unit will be, not merely relatively, but absolutely uneconomic*
(1) Ammonia ...	... 20,000 tons a year or 16,500 tons of nitrogen.
(2) Ammonium nitrate	... 60,000 tons a year or 21,000 tons of nitrogen.
(3) Ammonium sulphate	... 125,000 tons a year or 26,000 tons of nitrogen.
(4) Double Salt ...	... 100,000 tons a year or 26,000 tons of nitrogen.
(5) Urea ...	... 20,000 tons a year or 9,000 tons of nitrogen.

Should it be assumed, however, that the end products (2) to (4) will be produced from ammonia in a 60,000 tons/year ammonia plant, the minimum capacities indicated in Table III(A) in respect of these products would be lower and be roughly as follows:

TABLE III(B)

(2) Ammonium nitrate	... 22,000 tons a year (7,700 tons nitrogen).
(3) Ammonium sulphate	... 95,000 tons a year (20,000 tons nitrogen).
(4) Double Salt ...	... 70,000 tons a year (18,000 tons nitrogen).

4. These tentative conclusions can now be viewed in the context of our recommendations

(i) that the production target of 100,000 tons of nitrogen a year set for us should be achieved by arranging the manufacture of 65,000 tons of urea in addition to 275,000 tons of double salt, or, alternatively, an equivalent quantity of ammonium sulphate in terms of nitrogen; and

(ii) that urea manufacture should be associated with the manufacture of ammonium sulphate/ammonium nitrate/sulphate-nitrate and based, preferably, on the "once through" process.

It is obvious that if the manufacture of these end-products is to be arranged in economic units, the total production should be ideally established at the same location. To split it up even between two locations would inevitably involve the establishment of one or more uneconomic plant units. Assuming, for example, that the desired end-products are urea and double salt, the minimum capacities indicated in Table I in para 3 would mean a minimum production, in the

same plant group, of 22,500 plus 65,000=87,500 tons of nitrogen per year; and since it would, beyond question, be *uneconomic to arrange for a production of the small balance of 12,500 tons of nitrogen elsewhere, the correct course would be to instal plant units with slightly higher than the minimum economic capacity and thus secure closer approximation to the optimum capacities set out in the second Table in para 3. This conclusion would largely hold good even if it is assumed that the end-products desired are urea and ammonium sulphate except that it may then be possible to arrange for two units, one or both of them having one or more units below the capacities indicated in Table I but not below those indicated in Table IIIA or IIIB in para 3. Such an arrangement would, however, clearly fall short of the best attainable economic standards and must therefore be deprecated unless there are any compelling reasons, other than economic reasons, to favour it.

5. On purely *a priori* considerations, again, we conclude that the saving in distribution costs consequent on the multiplication of the number of production units and their convenient location near the main consumer points would be far from enough to counter-balance lower costs of production in a single unit. We refer in this connection to the calculations we have made in Annexure VII which will show that the net average *freight advantage* of a two-units or a three-units plant as compared with a single unit would be of the †order of Rs. 8 and Rs. 12 per ton of fertilizer. As against this we roughly estimate, from the statements in Annexure VI, that the corresponding *cost disadvantage* will be around Rs. 18 and Rs. 44, respectively, per ton of sulphate-nitrate. Even taking into account the factor of distribution costs, therefore, the net advantage lies clearly with a single production unit.

6. The conclusions set out in the last three paragraphs are however *a priori* conclusions based on certain assumed data and identical production conditions. They take no account of the advantages and limitations peculiar to the 11 locations we have tentatively selected for closer investigation, nor do they take any account of transportation problems. While there should be no doubt that on purely theoretical considerations the concentration of the entire new production of 100,000 tons of nitrogen at a single centre would be the soundest plan and would secure the best economic advantages, we recognise that available transportation facilities and other practical considerations based on potentialities and limitations of different locations may conceivably indicate a contrary course and favour a two-unit plan. We find it however impossible to visualise any circumstances where it may be expedient to sacrifice production economy to the extent of splitting up the new production between more than two units, and we would accordingly rule out from further consideration any such alternative. We proceed, then, *first* to set out the results of our factual investigations regarding the probable costs of production and distribution with reference to the selected locations; *next* to discuss, in

*As this would involve installation of an ammonia plant of a capacity below that indicated in Table III(A).

†This is on the assumption that since the new production will be required largely to meet the demands of Zones II and IIIB, the production units (whether single or multiple) will be located at a convenient place or places in these Zones.

the same context, facilities and limitations of railway transport; and *finally* to record our recommendations in the light of our examination of these two factors as well as the *a priori* and tentative conclusions we have reached in this section.

Section 2—ECONOMICS OF DIFFERENT LOCATIONS SELECTED FOR STUDY OF THEIR POTENTIALITIES

7. On the basis of the theoretical considerations discussed in Section 1 and also the conclusions about regional requirements which we have reached in Chapter II, we assume that in examining the issue of a single unit *versus* multiple units we shall have to consider one or other of the following alternative plans:

(a) a single plant group at the most convenient location producing 100,000 tons of nitrogen per year in the form of (i) 65,000 tons of urea; and (ii) 275,000 tons of double salt or an equivalent quantity, in terms of nitrogen, of ammonium sulphate;

(b) two plant groups at two locations, one producing two-thirds of the total urea requirement and half of the double salt requirement (alternatively, equivalent ammonium sulphate) and the other producing the balance of urea and double salt (alternatively, equivalent ammonium sulphate) requirements; and

(c) two plant groups at two locations, one group producing the entire urea requirement in association with 80,000 tons of double salt (alternatively, equivalent ammonium sulphate) and the other producing 195,000 tons of double salt (alternatively, equivalent ammonium sulphate).

If the plan of two plant groups is decided on, the choice, in our view, should lie between (b) and (c) above. In the former case (b), the division of total nitrogen production is in the ratio of 55:45; in the latter case (c), the division between the two units is more or less half and half. The advantage of the division visualised in (b) is that if fits in with the zonal requirements of Zone II and Zone IIIB; and further that at least one of the two urea units will closely approximate the minimum economic capacity indicated in Table I in para 3, and even the other urea unit as well as the double salt or ammonium sulphate units will be well above the capacities indicated in Table III(A). The advantage of the division visualised in (c) is that the maximum economy in urea production would be secured by its concentration at a single location. The associated double salt (alternatively, equivalent ammonium sulphate) unit will be just large enough to permit the adoption of the 'partial recycling' process for urea production and will at the same time be above the minimum capacity indicated in Table III(B). The other unit producing double salt or ammonium sulphate alone will, if it is an ammonium sulphate plant, have the minimum economic capacity specified in Table I in para 3 and, if it is a double salt plant, approximate that capacity fairly closely.

8. On the above basis we have calculated the likely production costs of the specified fertilisers (urea, double salt and ammonium sulphate) for five different plant combinations at each of the 11 locations provisionally selected in Chapter IV. We have also estimated

average *transportation costs per ton of fertiliser under each alternative scheme and added the same to the estimated costs of production For our present purposes we have assumed, in estimating production costs, that capital investments and wage bills will be identical for plants of identical size producing identical products, whatever their location. On the other hand, we have costed raw materials (like gypsum and coal) and utilities (like water and power), delivered to site, on the basis of the findings which we have arrived at during our local investigations and which have been set out in some detail in our review of the State Governments' proposals in Chapter IV. The results of these calculations and adjustments are summarised in the statements in Annexure VIII of which the first statement details the more important assumptions which we have made regarding certain basic data.

9. From the data available in the statements in Annexure VIII it is now possible to draw the following conclusions:

(i) Sulphate-nitrate would be a cheaper product to make than ammonium sulphate at any location irrespective of whether a single unit plan or a two-unit plan is favoured.

(ii) Of the two alternative two-unit plans, the one which visualises concentration of the manufacture of the entire urea requirement at a single location in association with a minimum quantity of sulphate-nitrate would ensure greater overall economy than the other alternative.

(iii) Compared with even the more favourable two-unit plan, a single-unit plan would yield better overall economy even after due adjustment of the higher freight charges. The cost per ton of †*delivered* nitrogen would, under the single-unit plan, be as follows at the four most promising locations:

	Rs.	A.	P.
(a) Neyveli	856	0	0
(b) Bombay	864	0	0
(c) Itarsi	920	0	0
and (d) Vijayawada	930	0	0

We can compare the above with the cost of *delivered* nitrogen per ton on the assumption that the more favourable two-unit plan will be adopted and the units will be located (a) at Neyveli and Bombay and (b) at Vijayawada and Itarsi. The overall cost of *delivered* nitrogen, with the locations assumed in (a), would come to Rs. 910 per ton and, with the locations assumed in (b), to Rs. 1,004 per ton. These costs are comparable with, respectively, the cost of *delivered* nitrogen from a single unit located at Neyveli, that is Rs. 856 and the cost of *delivered* nitrogen from a single unit located at Itarsi, that is Rs. 920. The difference in the former case comes to Rs. 54 per ton and in the latter case to Rs. 84 per ton. The net conclusion that can be reasonably drawn is that the adoption of a single unit

* On the assumption that the new production will be required to meet demands in Zones II and IIIB.

† Delivered to subsidiary distribution centres.

plan in preference to a double unit plan will result in an economy which in terms of money would be of the order of over Rs. 50 per ton of nitrogen.

(iv) Whether the basis is a single-unit plan or a two-unit plan, the siting of a factory at Vijayawada would have the greatest advantage from the point of view of economy in railway freight on *end-products; in other words, proximity to markets. Next in order come: (1) Ramagundam and Kothagudium almost in the same category, (2) Neyveli; and (3) Bombay, closely followed by Itarsi.

(v) From the point of view of economy in production the order of preference is as follows for the three products ammonia, urea and double salt in a single-unit plan:

Ammonia	Urea	Double salt
1. Bombay	1. Neyveli	1. Bombay.
2. Neyveli	2. Bombay	2. Neyveli.
3. Durgapur	3. Durgapur	3. Hanumangarh.
4. Vijayawada	4. Vijayawada	4. Hathras.
5. Itarsi	5. Itarsi	5. Itarsi.
6. Hanumangarh	6. Hanumangarh	6. Sikka.

(vi) From the point of view of overall economy the 11 locations can be conveniently placed in four categories as below:—

Category I	(a) Neyveli. (b) Bombay.
Category II	(a) Itarsi. (b) Vijayawada.
Category III	(a) Sawai Madhopur (b) Hanumangarh. (c) Hathras. (d) Kothagudium (e) Ramagundam.
Category IV	(a) Durgapur. (b) Sikka.

While there is not much to choose between the locations within the same category, all locations in any particular category are definitely more advantageous than those in the category next below. The selection of a location out of those placed in the same category should thus depend upon considerations of expediency and convenience such as comparatively lower capital investment, relatively better situation in respect of distribution of end-products or transportation of raw materials, ready availability of trained personnel and utilities and construction facilities etc. etc. If a choice were to be made, for example, out of the locations placed in category III, the choice should thus be in favour of Kothagudium or Ramagundam in preference to any of the other three locations.

* *Not* including raw materials. See para 11 *post*.

SECTION 3—TRANSPORTATION PROBLEMS

10. Our discussions with the Railway authorities have clarified the following main points:

(1) The flow of traffic from the North to the South, towards Madras and Bombay to be more specific, is at present appreciably greater than that in the reverse direction. If a single factory were, therefore, to serve the needs of both South and North, the Railways would prefer, from the point of view of transport economy, its location in the South rather than in the North, assuming of course that the plan would not involve bulk transportation of raw materials from the North to the South. They would, in any case, deprecate the location of a factory in the North if a great deal of its product is destined for areas in the South.

(2) Our attention has been specially drawn to the traffic congestion on the Vijayawada-Madras and Bhusaval-Igatpuri sections. With regard to the former, we have been told that while there is very considerable flow of goods traffic towards Madras, the reverse flow from Madras towards Vijayawada is not commensurate for which reason many wagons have to return empty. From the point of view of distribution of end-products alone, a factory at a place like Neyveli would thus mean utilisation of empties while one at Vijayawada would intensify existing difficulties. With regard to the Bhusaval-Igatpuri section, any increase in the flow of traffic from Bhusaval towards Igatpuri and Bombay would be unfortunate; on the other hand an increase in traffic in the reverse direction would be welcome.

(3) The Railways would deprecate the location of a factory at Vijayawada for more than one reason:

(a) Vijayawada may shortly cease to be connected on the metre gauge system since according to present plans, which are, however, still under consideration, the metre gauge on the Masulipatam-Vijayawada-Guntur section is likely to be replaced by broad gauge. If and when this programme is carried out, the advantage which Vijayawada has at present of being a junction of metre gauge and broad gauge systems would disappear.

(b) The present railway bridge on the Krishna is not wide enough to permit installation of double line. Consequently there is only a single metre gauge line and a single broad gauge line and even then only one metre gauge train or one broad gauge train can cross the bridge, up or down, at a time. This adds to traffic congestion at Vijayawada.

(c) Above all, the capacity of the single line between Vijayawada and Madras is limited and, as mentioned above, the flow of Madras-bound down traffic is much more than the reverse flow; any decision which would increase this trend would accentuate the present evil

of empties returning northwards to Vijayawada in large numbers.

We assume, however, with regard to (a) that should a factory be located at Vijayawada the railways are unlikely to proceed further with the plan to eliminate the convenience of its metre gauge connection. With regard to (b), the obvious solution which has got to be faced some time or other (and whether or not a factory is now sited at Vijayawada) is a second railway bridge on the Krishna, proposals in regard to which we understood in our discussion with the Andhra Government, are under consideration. Finally as regards (c), the argument appears to be not so much an argument against the location of a factory at Vijayawada in particular as it is a general argument against the location of a factory anywhere in India north of Vijayawada if some of its product is meant for consumption in areas south of Vijayawada and would thus be due to be transported *via* that station.

We understood that the capacity on the Vijayawada-Madras section is likely to be increased by certain improvements, particularly the conversion of the metre gauge section between Gudur and Renigunta into broad gauge which would provide an alternative broad gauge route between Gudur and Madras *via* Renigunta and Arkonam. We understand that the Gudur-Madras portion of the Vijayawada-Madras section suffers from the worst congestion and is the most heavily worked at present. We were told, however, that while the increased capacity will help to relieve the present congestion to a great extent it would not be sufficient to accommodate any new *extra* traffic towards Madras. We were told also that the present congestion of south-bound goods traffic on the Madras-Vijayawada section might be relieved further on the reduction of coal transport towards Madras which is expected to follow the development of the lignite reserves of South Arcot.

The Railway have, of course, no objection to the location of a factory at Vijayawada if all or practically all its end-products are distributed towards the north and the west. Transportation of Singareni coal to Vijayawada would create no special problem. Even transportation of finished goods towards south would be unobjectionable if most of it can be arranged by canal and sea routes upto Madras and thence by railway.

(4) Assuming that a factory at Neyveli would be based on local lignite and imported sulphur or Trichinopoly gypsum and, during construction, imported plant, machinery and equipment would be transported there *via* the Madras port along the metre gauge line connecting Neyveli with Madras, a factory located at Neyveli would present no special transportation problems except: (a) since Neyveli is connected only on the metre gauge system, the distribution of 70 per

cent or more of the end-product would involve transhipment from metre gauge to broad gauge at convenient points; and (b) provision of additional facilities would be necessary at Ariyalur for transportation of the required quantity of Trichinopoly gypsum to the factory site. We understood that existing transportation facilities from Cuddalore to Neyveli would not require any material improvement for handling sulphur/pyrites/gypsum imports.

(5) The location of a factory at Bombay would, generally speaking, present little transportation problem except such as may be purely local and capable of solution at no great cost. Should it be desired to bring Saurashtra gypsum by rail to a factory located near Bombay, transhipment would be involved at Viramgam, which can be arranged for without much trouble. The transport of end-products away from Bombay *via* Igatpuri-Bhusaval section would mean utilisation of the present flow of empties and would, therefore, be welcome. There would, of course, be difficulty if coal has to be brought from Bihar or Madhya Pradesh coal fields *via* Bhusaval, but the difficulty would not be of any significance if the Trombay refinery gases are adopted as the main raw material for synthesis of ammonia and only a small quantity of coal has to be transported. The congestion in traffic from Bhusaval to Igatpuri (but not in the reverse direction) is, we understand, very considerable at the moment and, although the capacity of the section is being stepped up to some extent, the congestion is unlikely to be eliminated until the section is electrified. A scheme for electrification of the section is, we were told, under consideration but it is unlikely to materialise in less than five years or so after it receives approval. Transportation of end-products from Bombay towards Madras *via* Raichur would present difficulties because the line beyond Raichur has limited capacity, and it would not be possible to accommodate any heavy increase in traffic *without* imposing restrictions on the movement of other commodities.

6) A location in the neighbourhood of Itarsi would be free from transportation problems except that the Bhusaval-Igatpuri and Vijayawada-Madras sections would be difficult for transportation of end-products towards the west and the south. Movement of gypsum from Rajasthan to Itarsi would present no difficulty and a convenient break-of-gauge point would probably be Sawai Madhopur. Agra, we understood, is highly congested and so would be Mathura on account of increased load in gypsum traffic from Rajasthan towards Sindri consequent on the approved plan of expansion of Sindri's sulphate production.

') A factory at Hanumangarh or Bikaner would involve transhipment difficulties in the despatch of the end-products to places outside Rajasthan and if some of the destinations are in the South or towards Bombay, the difficult sections Bhusaval-Igatpuri and Vijayawada-Madras will come in the way. From the transportation point of

view, Sawai Madhopur would be preferable to either Bikaner or Hanumangarh as a possible location.

(8) We understood that so far as the broad gauge railway system is concerned, further movement of gypsum from Rajasthan towards the east would be welcome but not further movement of coal from the Bengal-Bihar coal fields towards the west. There is, we were told, full utilisation, on their return journey, of broad gauge wagons going towards Sindri loaded with Rajasthan gypsum. Even then nearly a thousand empties have to be sent every day towards the Bengal-Bihar coal fields to bring coal to the western regions. On the northern metre gauge system also, the trend of traffic to and from junctions like Agra, Mathura and Bharatpur is from the east to the west.

(9) A factory located at Nangal would, according to the Railway authorities, present no special problems except, of course, that transhipment from broad gauge to meter gauge would be involved should any portion of the Nangal product be destined for places served by metre gauge railways. Movement of gypsum from Rajasthan in limited quantities would not cause any serious difficulties.

(10) From the point of view of transportation, the Railway authorities would consider the location of a factory at Agra definitely disadvantageous; and Mathura would be little better than Agra when it has to handle more gypsum traffic for Sindri. From the railway point of view Bharatpur would be a better location than either Agra or Mathura.

(11) In regard to other locations not specifically mentioned in the foregoing paragraphs, no special problems are anticipated except for the bottle-necks common to all locations north of Vijayawada and Bombay.

(12) A general conclusion which was pressed on our attention is that from the point of view of railway transport, two factories would be preferable to a single unit, one to serve the markets south of a line drawn from Vijayawada to Bombay and the other to serve the needs of areas north of this line. Should this be done, distribution would be regionalised resulting in quicker movement of wagons and avoidance of long hauls for reaching the end-products to their destinations. Also, the present railway facilities would not then require any significant improvement involving heavy capital expenditure and the main transportation bottle-necks mentioned above would be more or less satisfactorily avoided.

11. In the context of the above we may now proceed to consider the volume of new traffic and the magnitude of transportation problems that would be involved consequent on the location of a factory at any of the four most promising locations, *viz.* Bombay, Neyveli, Itarsi and Vijayawada. In Annexure IX we have attempted to tabulate our assessments on this issue taking into account transportation of both raw materials and finished products on the basis of a

100,000 tons/year nitrogen factory producing about 1,000* tons of fertilizers a day partly as urea and partly as double salt. The tabular statement gives full details of the quantities of raw materials required, the haulage involved in bringing them to the factory site and the new traffic that will be generated, in terms of ton/miles, for transporting end-products to their destinations. It will suffice to summarise here that the total ton/miles per day that will have to be handled for transportation of (a) raw materials and (b) finished products is as follows for each of the four locations:—

Location	Ton/miles/day for raw materials	Ton/miles/day for finished products	Total Ton/miles/day
1. Neyveli	37,800	587,000	624.800
2. Bombay	50[illegible],000	660,000	1,163,000
3. Itarsi	663,250	670.000	1,333.250
4. Vijayawada	1,194,000	444,000	1,638,000

SECTION 4—CONCLUSIONS

12. We would, to start with, note that as between the two alternative products, ammonium sulphate and sulphate-nitrate, our final preference, taking into account all relevant factors, is for the latter, whatever be the location or the capacity of the production unit. We recommend, in other words, that the production target of 100,000 tons of nitrogen per year (excluding Nangal) should be achieved by establishing the production of 65,000 tons of urea and 275,000 tons of double salt.

13. Before setting out our conclusions with regard to the manner in which and the locations at which the above production capacity should be established, we would refer to two points which have an important bearing on them. The first is the conditional nature of our conclusions with regard to the two provisionally selected locations at Bombay and Neyveli due to the circumstances which we have briefly explained in para 4 of Chapter IV. The other point relates to the expediency of increasing the production target which we have briefly discussed in para 15 of Chapter II. In our judgement no undue risks would be taken regarding the disposal of the quantities of end-products that would be available even if the target is stepped up to the full requirement† estimated by the Ministry of Agriculture: in other words, if the target of new production is increased from 170,000 tons of nitrogen to 250,000 tons per year. We are, in any case, of the opinion that it would be expedient and ultimately save avoidable delays if plans are immediately laid for a production of at least 50,000

*Total yearly production assumed to be 65,000 tons urea *plus* 275,000 tons double salt=340,000 tons.

†The only valid consideration that can be urged against this is that before long the Ministry of Agriculture may accept still cheaper forms of nitrogenous fertilisers e.g. more urea and nitro-limestone; and assuming that they would do so, it would be inexpedient, at the present juncture, to establish a larger production of double-salt.

tons of nitrogen a year over and above the target fixed for us. Accordingly, while we have made our recommendations within the limits set by our terms of reference, we have submitted certain alternative suggestions keeping in view the possibility that Government may be disposed to accept our suggestion for increasing the production target at least in part.

14. Subject to the above explanation we proceed to state below the unanimous conclusions we have reached after a careful consideration of all the pros and cons explained in the last three sections.

(1) We conclude that considered from any angle the best locations are Neyveli and Bombay, provided the assumptions we have made concerning them are substantially fulfilled. The two next best locations are, in our view, Itarsi and Vijayawada. We recommend accordingly that the choice of locations should be limited to these four places.

(2) As between Bombay and Neyveli any strict comparison is not possible if only because the potentialities of nitrogen production at Bombay, which can be foreseen at the moment, are limited to a maximum of 36,000 tons per year. Subject to this, the advantage of Bombay lies in the assumed availability of refinery gas at a reasonable price and also the availability of utilities like power and water more or less at the rates we have ascertained in the course of our enquiries. A fertilizer factory at Neyveli must, on the other hand, be regarded as an integral part of the South Arcot lignite exploitation scheme and must justify itself on the basis of cheap lignite on the spot as its main raw material. We assume that the bigger scheme of which the fertilizer unit will be a part will be so planned as to make the required quantities of power, steam and water available for fertiliser production at the prices assumed in Powell-Duffryn's report; and also that the fertiliser factory will not have to bear any portion of the capital investment required for the production of these utilities.

(3) As between Itarsi and Vijayawada, the main advantage of the former location is its nearness to coal and gypsum, while the economics of Vijayawada are dependent on its excellent situation as a distribution centre and availability of relatively cheap hydro-electric power. In comparing the economic advantages of Vijayawada with those of Itarsi we do not set much store by the nominal difference in overall economy of Rs. 10/- per ton of delivered nitrogen in favour of the latter location, particularly as our cost calculations at this stage are by no means meticulous and have been made on the basis of identical investments and wage bills for similar plants irrespective of locations. On the other hand, account must, we think, be taken of the following factors which favour the Vijayawada location as compared with Itarsi:

(i) capital investment at Itarsi would be considerably heavier because:

Firstly, a fertiliser factory located there will have to instal a large power plant for the production of

all the power which it will need while a factory at Vijayawada need only have a relatively small unit for the generation of steam and by-product power, Machkund hydro-electric power being available for normal factory operations;

secondly, pending the execution of the Tawa dam project, it will be necessary to take special measures to ensure security of water supply for which we have to provide for a fair amount of capital outlay;

thirdly, two short railway links will be necessary for connecting the factory site and the Pathakhera coal fields with the main railway system; and

fourthly, the exploitation of Pathakhera coal will mean the opening up of new reserves and may involve a certain amount of capital expenditure.

Even ignoring the point mentioned last we have estimated that the likely capital investment for a factory located at Itarsi would be about 25* per cent more than that on a factory with the same production capacity located at Vijayawada;

(ii) compared with Vijayawada, Itarsi has little construction potential; the entire organisation there will have to be built from scratch. Many facilities, for example, railway sidings, will have to be provided before even the required plant, machinery and equipment can be assembled at worksite. There is consequently little doubt that the construction of a factory at Itarsi will take somewhat longer time;

(iii) as a distribution centre for the finished products Vijayawada is a better location than Itarsi; and

(iv) the location of Vijayawada near a minor sea port gives it an added advantage, particularly in so far as it will facilitate bringing to the factory site imported machinery and equipment and other construction materials and also, should it ever be required, high grade imported gypsum from abroad.

As against the above advantages which Vijayawada has over Itarsi, the Itarsi location is distinctly advantageous in two important respects, namely,

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*According to the calculations we have made, a 100,000 tons/year nitrogen plant at Itarsi would involve a capital investment of Rs. 30½ crores while the capital expenditure for the same plant at Vijayawada would be Rs. 24¾ crores. Similarly, the comparative figures for a 86,500 tons/year nitrogen plant are: Itarsi —27.35 crores; Vijayawada —22.33 crores. The difference in either case is due mainly to (a) very much more expensive power plant (obout Rs. 6.3 crores in the case of the larger unit and Rs. 5.4 crores in the case of the smaller unit); (b) the necessary railway extensions (assumed to be Rs. 20 lakhs for 20 miles); and (c) a bund, on the Tawa dam which, together with pumping installations, is likely to cost at least 90 lakhs of rupees, probably a great deal more. Even if the Tawa dam project be given high priority and its execution is synchronised with the construction of the fertiliser factory, the difference in capital investment will still remain fairly large.

(i) it will involve far less haulage of raw materials, particularly gypsum (see Annexure IX) and, generally, appreciably less strain on railway transportation; and

(ii) because the location would be nearer to the Rajasthan gypsum reserves, the cost of production of double salt would be about Rs. 12/- per ton less than its production cost at Vijayawada, although ammonia and urea would be slightly more expensive at Itarsi than at Vijayawada.

Ignoring considerations of relatively minor importance and taking into account the fact that there is not, in the ultimate analysis, much to choose between Itarsi and Vijayawada in the matter of overall economy of production and distribution, it would appear that the two main factors which we have to balance against each other are:

(i) considerably heavier capital investment at Itarsi as compared with Vijayawada; and

(ii) *per contra*, Itarsi's distinctly better situation in the matter of nearness to sources of raw materials. In particular, haulage of gypsum for a factory located at Itarsi would be 600 miles less than the haulage involved for a factory located at Vijayawada.

Of these two factors, greater importance should, in our judgment, be attached to the former factor and for this reason (and no other reason) we have ranked Itarsi lower than Vijayawada in our order of preference.

(4) We are of opinion that utilisation of Trombay refinery gases should, if possible, be secured. In the first place, it is in the country's interest that these spare gases should be most advantageously used. Secondly, an ammonia plant based on refinery gas involves relatively low plant investment and ensures trouble-free operation. Even assuming, therefore, the availability of no more than 2.3 m. cu. ft. of gas from Stanvac refinery (which is assured), we would recommend the establishment of a fertiliser production unit at Trombay provided a fair price can be negotiated for the gas. In Chapter III we have indicated that the maximum price which can, in our opinion, be agreed to for the gas (and which would in our view be quite fair to the seller) is the cost of equivalent coal delivered at Bombay on B.T.U. basis. Assuming that the cost of coal brought to Bombay is Rs. 35 per ton, the ceiling price of gas on the basis suggested by us would amount to 25 annas per million B.T.U. or about Rs. 3/2/- per thousand cu. ft. Provided a minimum quantity of Trombay refinery gas is available for this price, we have reckoned that with the facilities available at Bombay ammonia can be economically made and an end-product like ammonium sulphate or double salt can be manufactured, even in a relatively small nitrogen fixation plant, at costs which will favourably compare with Sindri's production costs. We estimate, on the basis of the composition of the Stanvac gas furnished to us, that about 140 tons of ammonia per day can be made from the quantity of Stanvac gas which, we have been assured, will

be available. We would recommend that this ammonia production should be utilised to make only *one end-product, namely, sulphate-nitrate of which the total yearly production will then be 138,000 tons with a nitrogen content of 36,000 tons. If the conditions we have stipulated materialise, the economics of a 36,000 tons/year nitrogen plant at Bombay on the basis of utilisation of refinery gases would compare very well with those of a 70,000 or even 75,000 tons/year nitrogen plant any where else.

(5) We have not considered at this stage the possibility of Burmah-Shell's offering to sell their spare gas on acceptable terms. Should any such offer be forthcoming at any time in future, we presume that Government will decide, in the light of the circumstances then existing, whether and, if so, in what manner and to what extent the offer should be availed of. If for example, the offer is made early enough to admit its consideration in the context of the current programme, the size and capacity of the other production unit we are recommending, or even the decision to instal it, may have to be reconsidered or, again, it may be considered more expedient to step up the total production target to the necessary extent so as to accommodate both a larger Bombay unit and the other unit. Which of these various alternatives would be most expedient would depend on the circumstances existing at the time the offer is received; all that we are in a position to point out at present is that if a relatively small production unit is installed at Bombay at present, there will be plenty of room for its expansion and any plans that may now be laid should, accordingly, be so devised as to permit such expansion with ease and convenience.

(6) Assuming establishment of production facilities at Bombay for 138,000 tons of double salt per year, it will be necessary to arrange for, at some other location, the production of the balance of 65,000 tons of urea and 137,000 tons of double salt. To establish this production at any location would involve two difficulties, namely, (i) the urea manufacture will have to be based on the partial recycling process which, for technical reasons, should be avoided, if possible; and (ii) the double salt unit would not be economic by the standards we have suggested even though its production will be associated with a relatively large ammonia plant. If, therefore, it is decided that the production target fixed in our terms of reference should not be appreciably exceeded, we would recommend that urea production should be reduced to some extent, double salt production being then correspondingly increased. We would, to be more precise, recommend that the second production unit should have facilities for the production of 46,000 tons of urea and 200,000 tons of double salt. This re-arrangement would bring both the urea production unit and the double salt production unit up to reasonably economic sizes and would also permit production of urea by

*To split up the small quantity of ammonia between two end-products like urea and double salt will be uneconomical.

the "once through" process. The nitrogen capacity of the unit will then be 72,700 tons per year and the total nitrogen capacity of the Bombay unit and the second unit taken together would be 108,700 tons involving an excess of only 8,700 tons of nitrogen per year over our target, which, we assume, will not be regarded as a matter of any great consequence.

(7) We would, however, urge that in planning the second production unit a somewhat larger increase in the production target should be agreed to in order that there may be no need to reduce the urea production capacity below 65,000 tons a year and at the same time a higher level of overall economy may be achieved. We would recommend accordingly that the second production unit should be designed to produce the entire urea requirement of 65,000 tons a year and simultaneously enough double salt (220,000 tons a year) to permit the adoption of the "once through" process for the urea manufacture. The nitrogen capacity of the second unit would then be 86,500 tons a year and the total nitrogen capacity of the Bombay unit and the second unit taken together 122,500 tons a year.

(8) We recommend that the second production unit having the capacity indicated in either para (6) or para (7) should be established at Neyveli. This recommendation is, however, conditional on the due fulfilment of the assumptions on which we have worked out economics of production at Neyveli. We refer in this connection to paras 5—8 in Chapter III and the statement of assumptions (Statement I) in Annexure VIII. We have no means of judging, in the first place, how soon the further studies and investigations now in progress at Neyveli will be completed nor how far the final data arrived at on their completion will confirm the tentative conclusions, particularly the cost calculations, recorded in Powell Duffryn report. All that we can do at present is to point out that if the final data indicate any need for upward adjustment in the assumed prices of lignite, power, etc. at Neyveli, the overall economy in its favour would be upset and Neyveli may then rank lower than other locations on our order of preference. In case, therefore, the present expectations about Neyveli economics are ultimately belied* or Government wish to take an immediate decision without waiting for a clear demonstration of the due fulfilment of those expectations, more particularly the anticipated cost of lignite mining assumed in Powell Duffryn report, we would recommend that the second production unit should be located at Vijayawada.

(9) In case a fair price for the Stanvac gas cannot be successfully negotiated, our recommendations in the foregoing paras (4) to (8) would not arise for consideration at all. In

*To such an extent, of course, as to justify a clear preference for the next best location, Vijayawada.

that event and on the assumption that Government would be unwilling to increase the production target fixed in our terms of reference, we would recommend that the entire production of 65,000 tons of urea and 275,000 tons of double salt should be established at a single location. A single unit designed to produce these quantities of urea and double salt will not by any means be too large a unit. In fact, the unit would fit in with our idea of the "optimum" size of an ammonia production unit, though the level of urea production and double salt production would still remain below the "optimum" standard. Almost every economic consideration would favour this arrangement in preference to an arrangement which visualises splitting up the production between two units. For instance, (a) capital investment in plant and equipment will be lower by Rs. 5½ crores (b) production costs of ammonia, urea and double salt would be lower by Rs. 70, Rs. 40 and Rs. 25 per ton respectively; (c) even allowing for higher freight charges for distribution of the end product, the net minimum overall economy that will be secured, compared with any two-unit plan, will be of the order of Rs. 54 per ton of nitrogen delivered at subsidiary distribution centres. We recognise, on the other hand, that the physical transportation of end products from a single large unit will involve a bigger problem, but the problem will not be, in our view, one of any really serious *magnitude. We agree that transportation facilities will have to be improved but this improvement is in any case necessary with the rapid industrialisation of the country; not only fertilisers but many other commodities are going to be transported on internal railway routes in ever increasing quantities. We assume in the circumstances that railway transportation facilities cannot remain static but suitable expansion schemes will be devised and put through so as to keep pace with the progress of implementation of the development plans now under execution.

(10) If, as suggested in the last para (9), it is decided that the entire production of 100,000 tons of nitrogen per year should be established at a single location, the location should, we conditionally recommend, be Neyveli. If it should be necessary to rule out Neyveli in any of the circumstances explained in para (8), we would recommend that Vijayawada should be selected as the next best location.

(11) We would urge, however, here again, that the production target should be increased to an extent which will admit the establishment of two independent production units at two different places without any sacrifice of the overall economy that it is possible to achieve by establishing a production of 100,000 tons of nitrogen at a single location. We have estimated that the *minimum* increase necessary to secure this end is 50 per cent of the present target (excluding Nangal), that is, about 50,000 tons of extra

*There would, indeed, be no problem at all if a single large unit is ocated at a place south of Madras City like, for example, Neyveli.

nitrogen per year. Should this increase be agreed to, we would recommend that the size and production capacity of one of them should be the same as what we have recommended in para (7), that is, 65,000 tons of urea 220,000 tons of double salt per year. The other unit should then be designed to produced 250,000 tons of double salt alone. The nitrogen capacity of the latter unit will be 65,000 tons per year and the total nitrogen capacity of the two units 151,500 tons per year. The advantages that would follow on the adoption of this plan are:

(a) no unit will be uneconomic by the standards we have fixed;

(b) the maximum economy in urea production will be secured by its concentration at a single location;

(c) it would at the same time be possible to arrange for manufacture of urea by the "once-through" process;

(d) on the assumption that the locations we are suggesting for the two units in para (12) below will be accepted, distribution facilities will be almost ideal and minimum transportation would be required for either raw materials or end-products;

(e) the average cost of production per ton of nitrogen in the end-products will be Rs. 175 lower than that in the Sindri plant. Further, as mentioned above, the cost of *delivered* nitrogen will be no higher than what it would have been, had a production of 100,000 tons of nitrogen been arranged at a single location; and

(f) despite an increase of about 50,000 tons of nitrogen in the production target set for us, the total nitrogen production would still be about 30,000 tons short of the total requirement estimated by the Ministry of Agriculture. On the other hand, the total urea and double salt production (including the production planned at Sindri) would be more or less the same as the Ministry's "requirement",† in terms of nitrogen, of these two fertilisers taken together. As between these two fertilisers, our recommendation involves the production of a somewhat larger quantity of double salt and a correspondingly smaller quantity of urea than what has been suggested by the Ministry; this re-arrangement is in our view expedient having regard to our lack of experience of use of urea as an all-purposes fertiliser and the admittedly limited field of its application.

We admit, on the other hand, that the strain on the country's administrative and technical resources, particularly on trained personnel, would be great (but in our view not *too* great) if three production units (including Nangal) were to be installed simultaneously so as to achieve a total nitrogen production of 220,000 tons a year. In any case, the strain will not be appreciably heavier than what would be involved in building and commissioning two

†See Annexure IV.

50,000 tons/year nitrogen plants at two locations in addition to a 70,000 tons/year nitrogen plant at Nangal. In this matter what really matters is not so much the size of individual units as their total number.

(12) Assuming that the increase in production target suggested in para (11) will be approved, we would recommend that the larger unit designed to produce 65,000 tons of urea and 220,000 tons of double salt a year should be installed at Neyveli and in case Neyveli has to be ruled out in the circumstances explained in para (8), at Vijayawada. The other unit designed to produce 250,000 tons double salt a year should, we recommend, be installed at Itarsi.

15. We regret that we have had to make a number of alternative recommendations. This has been unavoidable owing to two factors: (i) our decision to take into account Bombay and Neyveli locations subject to due fulfilment of certain conditions which we have at the moment no means of establishing. As explained before, we have taken the view that it would be wiser to do so than rule out these two locations despite their great promise; and (ii) our assumption that Government may be disposed to accept our suggestion for increasing the production target fixed in our terms of reference. Subject to the above, our recommendations are definite and categorical enough and Government would have, we expect, no difficulty in reaching a decision on them according to such view as they may take in regard to the two factors (i) and (ii). We can best summarise our recommendations in the form of the following chart which will show that we have visualised four different plant combinations and four different locations, the selection of one or the other of which will depend upon Government's decision on factor (ii) and factor (i), respectively.

Plant Combination	Units with yearly production capacity and their location	Total annual production in terms of (*a*) fertilisers and (*b*) nitrogen	Remarks
(1)	(2)	(3)	(4)
I	138,000 tons Double Salt (36,000 tons nitrogen) at Bombay. 46,000 tons Urea and 200,000 tons double salt (72,000 tons nitrogen) at Neyveli, and failing Neyveli, at Vijayawada.	338,000 tons double salt and 46,000 tons Urea [108,700 tons nitrogen].	To be taken into consideration only it at least 2·3 million cu.ft.of refinery gas is available at Bombay for a fair and reasonable price.
II	Do. 65,000 tons urea and 220,000 tons double salt (86,500 tons nitrogen) at Neyveli, and failing Neyveli, at Vijayawada.	358,000 tons double salt and 65,000 tons urea [122,500 tons Nitrogen].	To be taken into consideration only if (*i*) at least 2·3 million cu.ft.of refinery gas is available at Bombay for a fair and reasonable price; and (*ii*) Government approve increase of production target by 22,500 tons of nitrogen per year.
III	65,000 tons Urea and 275,000 tons double salt (100,000 tons nitrogen) at Neyveli, and failing Neyveli, at Vijayawada.	Same as in Column 2	To be taken into consideration if even a minimum quantity of Bombay refinery gas is not available at a fair and reasonable price.
IV	250,000 tons of Double Salt (65,000 tons nitrogen) at Itarsi. 65,000 tons Urea and 220,000 tons double salt (86,500 tons nitrogen) at Neyveli and failing Neyveli, at Vijayawada.	470,000 tons double salt and 65,000 tons Urea [151,500 tons nitrogen].	To be taken into consideration if (*i*) even a minimum quantity of 2·3 million cu. ft. of refinery gas is not available at Bombay for a fair and reasonable price and (*ii*) Government approve increase of production target by 51,500 tons of nitrogen per year.

CHAPTER VI—TECHNICAL, FINANCIAL AND ADMINISTRATIVE CONSEQUENCES

A—TECHNICAL

In our interim report on the Nangal Project (Annexure III) we concluded that the only type of nitrogenous fertilizer that can be most conveniently and economically manufactured at Nangal is ammonium nitrate diluted with a suitable inert material so as to eliminate its explosion hazards and, to such extent as may be possible, improve its keeping quality. Two questions which we left unsolved were (i) the selection of a suitable diluent; and (ii) the determination of the extent of reduction of nitrogen content of pure ammonium nitrate in order to ensure complete elimination of its explosion hazards. As we indicated in our interim report, these two questions were remitted by us for study and investigation to the Sindri Technological Organisation. Copies of the reports embodying the results of the investigation which we have since received from Sindri are enclosed (Annexure X).

2. With regard to the issue of appropriate reduction of nitrogen content of ammonium nitrate, we endorse the opinion of the Sindri Technological Organisation and recommend that in the present circumstances, it would be unwise to contemplate use of more than 60 per cent pure ammonium nitrate, in other words, a higher nitrogen content than 21 per cent in the final product. On purely theoretical considerations it may be deemed safe enough to reduce the nitrogen content in the end-product to only 25 per cent. We understand that this indeed is the approved percentage of nitrogen in the end-product of an ammonium nitrate factory recently built in *Finland by Messrs Uhde of Dortmund, West Germany. We have been told on reliable authority that suitably diluted ammonium nitrate with 22.5 per cent nitrogen content should in any case be regarded as absolutely safe. Taking into account, however, not only the current practice in most European countries but the severity and extremities of Indian climate and the unfortunate consequences (particularly the set-back to the continued use of chemical fertilisers) that will follow in the wake of even a single minor mishap, it would, we consider, be wise to begin with a nitrogen content of 21 per cent in the end-product which is absolutely and unquestionably safe; and later on, increase it, perhaps by stages, to such extent as may be found safe and expedient in the light of further experimental studies as well as practical experience. In any case, we definitely rule out the use of pure ammonium nitrate in India, despite American practice to the contrary and a fair amount of documentary support in its favour which has been brought to our notice by or through Dr. Frank Parker of T.C.M. We do so chiefly because of the peculiarity of our climatic conditions: the hot and dry climate in the north is likely, in our opinion, to aggravate the explosion risks of ammonium nitrate; on the other hand the humid conditions in the south associated with high temperatures are certain to make it almost unusable as a product which has to be kept in storage and also transported over fairly long distances.

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*Typpi Oy. (Nitrogen Company), Oulu, Finland. Ammonium nitrate is treated with dolomite to reduce the nitrogen content to 25 per cent and then coated with talcum to prevent coalescence.

3. In regard to the nature and kind of diluent, we would, in the first place, deal with one or two suggestions which have been recently brought to our notice. One suggestion is that the Nangal plant may be designed to produce nitro-limestone on orthodox lines, the product being earmarked for use not in the Punjab and its adjoining regions where the soils are mostly calcareous but in the heavy or moderately heavy rain-fall areas in the south and the east where the soils are generally acid. The other suggestion is that the plant may be designed to produce sulphate-nitrate or double salt. We regret we do not see much advantage in either of these two suggestions. The first suggestion hardly merits serious consideration if only for the reason that the cost of nitrogen delivered to consumer points would be far too high if the product of Nangal has to be carried over long distances. There can, we think, be no question that the Nangal plant should be designed to produce a fertiliser suitable for the areas in its immediate neighbourhood. As regards the second suggestion, the difficulty is that according to Government's directive the Nangal plant has to be designed to produce ammonia as well as heavy water as a co-product. To achieve this end, the process for ammonia synthesis must be based on electrolytic decomposition of water. The adoption of this process means in turn that carbon dioxide, which is an essential raw material for the manufacture of ammonium sulphate by the gypsum process, will not be readily available as a co-product but will have to be especially arranged for by, for example, burning coal or limestone, which will be unduly expensive. Use of cabon dioxide can, of course, be avoided if ammonium sulphate is made by the sulphuric acid process, but here again the process is likely to be extremely expensive if sulphur is imported by sea to a convenient sea port like Kandla or Bombay and transported by rail from there to the factory site at Nangal. Any idea of making sulphuric acid from gypsum (with cement as a by-product) must also, we think, be ruled out on economic considerations; apart from the fact that the process is expensive and plant investments heavy, a cement-sulphuric acid plant, if ever one is installed in India, should, we think, be located at the source of gypsum. We do not see any particular reason why sulphate-nitrate must be produced in any of these expensive ways at Nangal when a suitable type of ammonium nitrate fertilizer can be made there far more economically. In the opinion of the Agricultural Commissioner and his expert advisers (see Annexure IV) such a fertiliser would be entirely suitable for the consuming regions for which Nangal would be a convenient supplying centre, provided the diluent used is an inert non-alkaline material. In our discussion with these officials, it has indeed been clarified that there would be no objection to the dilution of ammonium nitrate with chalk so as to bring down its nitrogen content from 35 to 30 per cent: admixture of lime to this very limited extent would not, in their view, be harmful to the calcareous soils for which the product is intended. For bringing down the nitrogen content any further, however, some other diluent must, in their view, be brought into use.

4. The reports we have received from the Sindri Technological Organisation (Annexure X) will indicate that there are two possible ways in which the ammonium nitrate to be produced at Nangal can be suitably diluted so as to meet the Agriculture Ministry's specifications, namely, (i) with 40 per cent low grade gypsum in the end-

product; alternatively, 26 per cent gypsum and 14 per cent chalk locally obtained; and (ii) with 40 per cent clay; alternatively 26 per cent clay and 14 per cent chalk. It has been mentioned that after the first world war ammonium nitrate in admixture with gypsum was produced on a commercial scale in Germany with "excellent results". Treatment of ammonium nitrate with mud or clay is also not without precedent. We understand that for a period of about four years from 1932 to 1936 some 200,000 tons of clay-ammonium nitrate was produced by Staatsmijnen of Limburg, Holland in the circumstances explained in an extremely interesting* report dated the 28th July 1948 by Mr. Van Aken, of which we enclose a copy (Annexure XI). The Aken report indicates that the manufacture of clay-ammonium nitrate caused no technical difficulties; that the mixing of standard quality ammonium nitrate and clay was easily done; and that the mixture had a constant homogeneity. To quote from the report "the product was readily sold and could be stocked and transported without caking or losing its free running quality. The whole process proved to be very attractive and was replaced by the lime-ammonium nitrate production solely because of the preference of Dutch farmers for nitrolimestone". As regards the quality of mud or clay to be used as a diluent, we draw attention to the recommendation in the Aken report that the clay or mud should have (i) particles as fine as possible; (ii) not more than 3 per cent organic matter; and (iii) the smallest possible content of sand.

5. Since precedents are available for the manufacture of both gypsum-ammonium nitrate and clay-ammonium nitrate on a commercial scale, we are in a position safely to recommend the use of either clay or gypsum as a suitable diluent for the ammonium nitrate to be produced in the Nangal plant. After a careful consideration of all relevant factors, we would indicate our preference for a clay-*cum*-chalk diluent chiefly for economic reasons. We have roughly estimated that as compared with ammonium nitrate diluted with chalk and clay, ammonium nitrate diluted with gypsum and chalk will be Rs. 6 more expensive per ton of end-product, even on the basis of utilisation of low grade gypsum for which we have assumed a pit-head price of only Rs. 4 per ton. We do not see sufficient justification for incurring this extra cost and accordingly recommend that the end-product to be established at Nangal, which may suitably be named as "Nangal salt", should have ammonium nitrate, local clay and powdered limestone from the nearest limestone deposits in the following proportion:

Ammonium nitrate—60 per cent.

Clay—26 per cent.

Chalk—14 per cent.

Certain samples of local Nangal clay have been processed at Sindri, but it has not so far been possible to obtain any conclusive data. We are confident, however, that the selection of a suitable type of local clay should present no insuperable difficulty; but special care should be taken to ensure that whatever clay is selected for diluting ammonium nitrate fulfils the Aken specifications quoted above and is also free of carbonaceous matters.

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* The Aken report forms Appendix 9 to the report of the International Commission on Synthetic Nitrogen Manufacture in Egypt.

6. We have recommended that the other plant or plants which will be set up, in addition to the Nangal unit, should be designed to produce urea and double salt. We have already indicated our view that for urea manufacture the adoption of the "once through" process should be the invariable rule so far as the present expansion programme is concerned. All alternative plant combinations which we have recommended will permit the adoption of this process. With regard to double salt, the ideal plan would be to arrange for the manufacture of a chemically homogeneous compound, in other words, of what is commonly known as the "true double salt". Even though this arrangement may not be practicable for the reason that the ammonium sulphate component of double salt will, according to our recommendation, be made by the gypsum process, we recommend that special efforts should be made (as are indeed being made at Sindri) to ensure that the end-product closely approximates the physical, chemical and mechanical properties of true double salt. In examining the Sindri expansion scheme, three of us went to a great deal of trouble in devising certain specifications for the double salt to be manufactured at Sindri; we suggest for consideration that the same specifications (of which a copy is enclosed—Annexure XII) should be laid down in regard to all new production of sulphate-nitrate under the present programme.

7. We come, finally, to the important subject of ammonia synthesis. The basic raw materials for production of hydrogen for ammonia synthesis which we have visualised for different locations are: (i) refinery gas at Bombay; (ii) water and electricity at Nangal; (iii) lignite at Neyveli; and (iv) non-coking coals at Itarsi and Vijayawada. With respect to (i), we have already recommended in paragraph 18 of Chapter III that whatever process may be selected for the cracking of refinery gas, it should be suitable for the simultaneous processing of mineral oil fractions also. The selection of a suitable process which will achieve this end should present no difficulty; and though the first costs involved may be somewhat high, the installation of a process fulfilling this important requirement would be justified by continuity of operations and resultant higher stream efficiency. Apart from this point, the choice of the process would lie between (i) steam methane cracking; and (ii) partial oxidation, in the presence of catalysts or without catalysts in either case. Processes based on steam methane cracking are older, more orthodox and well-established; further they involve less capital outlay; on the other hand losses of heat in flue gases and radiation losses from the combustion furnaces bring down the total heat efficiency and consequently the yield of synthesis gas as well. Losses of heat are minimised and therefore the resultant yields of synthesis gas are higher under any process employing partial oxidation. On the other hand, partial oxidation processes are of a comparatively recent origin and involve a larger initial investment; also certain technical troubles which are usually encountered, especially those connected with soot formation, have not yet to our knowledge been overcome with complete success. These troubles are, however, not of a very serious nature; and should the offer of a partial oxidation process be made with satisfactory guarantees as well as evidence to show that such troubles as soot formation have been successfully overcome in a plant operated on a commercial scale, the offer should, we recommend, be considered on its merits. The selection of either a suitable

partial oxidation process or a process based on steam methane cracking for utilisation of Bombay refinery gases must, of course, await a detailed examination of the economics of such offers as may be received in the light of all relevant factors as, for example, capital outlay, consumption of power, consumption of fuel for steam generation and comparative yield of synthesis gas. *Prima facie,* however, we are inclined to think that it would be more expedient and economical to select a suitable partial oxidation process despite the larger capital outlay that this will involve. The adoption of such a process will permit not only the use of mineral oil fractions as an alternative raw material to make good short supply of gas during shut-downs of refinery cracking units, but also utilisation of liquid nitrogen wash for purification of gas since liquid nitrogen would be available as a by-product in the manufacture of oxygen, which is an essential feature of any partial oxidation process.

8. The process for electrolytic decomposition of water which will have to be adopted at Nangal is well-known and does not require any elaboration; nor would we venture, in the absence of adequate knowledge on our part, to express any view with regard to the suitability of any particular process for manufacture of heavy water. We have already explained that the economics of the electrolytic process for ammonia synthesis depend almost completely on availability of cheap power. Since the manufacture of a ton of ammonia by the electrolytic process requires as much as 13,000 to 14,000 Kwh of power, the cost of power must range around 2 pies per unit to make the process competitive with a process based on gasification of coal or coke.

9. By far the largest source of hydrogen for the manufacture of ammonia is water gas or semi-water gas produced by the gasification of coke. Other carbonaceous materials such as lignite or coals are also used for production of synthesis gas but not to the same extent as coke. The chief reason why water gas from coke is being so extensively used for production of synthetic gas is that in connection with the supply of town gas, manufacture of water gas was already well-established when the ammonia industry was introduced; adaptation of normal water gas generators for the production of semi-water gas, which gives synthesis gas mixture in one step, was thus possible with comparative ease. Besides, gas produced from coke is relatively free from hydro-carbon inerts the presence of which seriously brings down the efficiency of an ammonia plant. On the other hand, the trouble with gas produced from other carbonaceous materials rich in volatiles, such as lignite or coal, is that the residual content of hydro-carbon in the gas is very considerable and difficult to remove. Further, only certain special kinds of coal can be used in the stationary type of generators which are normally used for the production of water gas. Another reason why direct gasification of coal has not found much favour in Europe uptil now is the parity in the price of coal and coke, especially in Germany. A plant designed to process coal for production of synthesis gas is more expensive than one designed to process coke. This is because costly equipment is required to purify coal gas from tar and other impurities and to rid it of hydro-carbon fractions in order to make it suitable for synthesis purposes. On the basis of more or less equal prices of coal and coke it is thus economical to produce gas from coke rather than from coal. In India, however, the conditions are different. Firstly, our reserves

of coking coals are limited; with the increasing demand on coking coals by the rapidly expanding steel industry, the position regarding supply of coking coal is likely to become difficult. Secondly, there is great disparity between the prices of coke and coal in India, the price of coke at some places being almost or quite twice the price of coal. Our studies have led us to conclude that in spite of higher initial investment, ammonia produced by coal gasification would, at most locations in India, be just as cheap as that produced by gasification of coke. Having regard to these considerations and also the fact that a large number of processes have now been developed, mostly in Germany, for the direct gasification of coal and a number of plants based on one or other of them are operating in Europe as well as in Japan, we would recommend that for the production of synthesis gas in future in this country gasification of coke should be avoided and gasification of coal or lignite should be the normal rule. This, in any case, is the source of hydrogen we visualise for the recommended locations at Neyveli, Vijayawada and Itarsi.

10. The principal processes available for production of synthesis gas from coal are:—

(1) *The Winkler process* in which pulverised coal is gasified in a cylindrical generator with steam and oxygen-enriched air. The velocity of blast is kept fairly high so as to maintain the fuel bed in a "boiling" state. The fuel bed is maintained at a uniformly high temperature ranging between 1100° and 1200° C; and the gas that is produced from the generator is reported to be free from methane and to contain about 45 per cent H_2, 43 per cent CO and 2.5 per cent CO_2. The generator was originally developed by I.G. Farben to gasify lignite for production of synthesis gas and has since been adapted for gasification of pulverised coal. Thermal efficiencies as well as carbon efficiencies in the process are understood to be low, the former being only 65 per cent. Only non-coking coals are suitable for processing and they should preferably have a low ash content of 8 to 10 per cent as otherwise the carbon losses are likely to be excessive resulting in extremely low thermal efficiencies.

(2) *The so-called re-cycle process*—Gasification is carried out in two stages, the equipment for both stages being built into the same generator body. In the first stage volatiles are distilled off at a low temperature in a distillation retort and in the second stage the partly coked coal is gasified in the main generator more or less as in a normal water gas generator. Gas from the distillation retort is passed through electrostatic precipitators to remove tar, which forms a valuable by-product, and after the tar-free gas is heated in regenerators, it is recycled into the main generator base. Since a high temperature has to be maintained at the bottom of the generators for the cracking of hydro-carbons, it is necessary to use coals having a high fusion point as well as a low ash content. We understand, in fact, that coals containing more than 8 per cent ash would not be suitable for the type of generators which are used for the recycle process. If coals with relatively high ash content have to be used, the arrangement that is usually adopted is not to recycle the hydro-carbon fractions in the generators but pass them through a cracking unit as is the normal practice in processing natural gas or other gases rich in hydro-carbons. The water gas is then mixed with cracked gas and the mixed gas is processed to yield synthesis gas. Messrs. Gas Integral,

who are the best known makers of "recycle" generators, claim that even mildly coking coals can be processed so long as their swelling index is not high; admittedly, however, it is always preferable to use non-coking coals.

(3) *The process developed by Messrs. Lurgi*—The Lurgi generator was developed primarily to produce town gas but has recently been adapted for the production of synthesis gas. Lurgi generators are, we understand now under installation at two plants; one in *South Africa where the gas would be cracked under pressure using partial oxidation process and the cracked gas would then be used for Fischer Tropsch synthesis; and the other in Pakistan where the gas obtained from the Lurgi generator will be purified from methane and other impurities by liquefaction and fractionation.

(4) *The Koppers Totzek process* which has been perfected in recent years for production of synthesis gas by Messrs. Koppers of West Germany. The process uses pulverised coal which is mixed with steam and oxygen and burnt partially in specially designed burner nozzles. The process has been adopted on a commercial scale at Oulu in Finland and three more plants based on it are reported to be under erection or planning in Japan, France and Spain. Another plant using the same process is reported to be under consideration in Ireland on the basis of utilisation of peat. The process is apparently versatile and is, we understand, capable of using any type of fuel such as high ash coal, lignite, peat or even fuel oil or any hydrocarbon stream. Although non-coking coals are preferred, the Koppers Totzek process is said to be suitable for using both coking and non-coking coals. The thermal efficiency of the process, including the heat of the steam, is reported to be 75 per cent to 77 per cent and carbon efficiency as high as 95 per cent to 98 per cent. The plant is, we understand, a little difficult to operate, particularly as a large number of control instruments are necessary for safe operation at all stages. The capital outlay involved is also rather high because of the highly mechanised nature of the plant and the requirement of a large sized oxygen plant. On the other hand, the versatility and high thermal efficiencies of the process are factors definitely in its favour.

11. We would, at this stage, refrain from indicating any definite preference for one or other of the four processes we have discussed above for gasification of coal or lignite. The selection of one or other of them at the three locations, Neyveli, Vijayawada and Itarsi would depend naturally on cost considerations and also a detailed investigation of their suitability for the type of fuel available at these places. We note, however, that in calculating our costs of production of ammonia from coal or lignite, we have assumed the use of the process mentioned last in the previous paragraph, that is, the Koppers Totzek process.

B—FINANCIAL

12. In the recommendations we have made in Chapter V we have visualised installation of one or more of the following plants:

(1) a 36,000 tons/yr. nitrogen plant at Bombay producing 138,000 tons of double salt a year;

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* According to our information, the installation of the South African plant is complete or very nearly complete.

(2) a 72,700 tons/yr. nitrogen plant at Neyveli or at Vijayawada producing 46,000 tons of urea and 200,000 tons of double salt;

(3) a 86,500 tons/yr. nitrogen plant at Neyveli or at Vijayawada producing 65,000 tons of urea and 220,000 tons of double salt per year;

(4) a 100,000 tons/yr. nitrogen plant at Neyveli or at Vijayawada producing 65,000 tons of urea and 275,000 tons of double salt per year; and

(5) a 65,000 tons/yr. nitrogen plant at Itarsi producing 250,000 tons of double salt per year.

We have thus proposed five alternative plants for three out of which we have proposed two alternative locations each; in other words, a total of 8 alternative units, taking an identical plant recommended for two alternative locations to be two separate and distinct units. In Annexure XIII we have estimated the capital investment that would be required for each one of these eight units; and in Annexure XIV we have estimated the likely costs of production of the end-products contemplated at each of them. Annexures XIII and XIV include also our final figures for the Nangal plant which according to the recommendations we have submitted in our interim report, will have a production capacity of 70,000 tons of nitrogen or 340,000 tons of diluted ammonium nitrate a year. The following table is a convenient summary of the capital and working costs estimated by us in respect of the nine units inclusive of the Nangal unit.

TABLE

Capital and Working Costs of Alternative Schemes

Plant capacity	I	II		III		IV		V	VI
Nitrogen tons/yr ..	36,000	72,700		86,500		100,000		65,000	70,000
Ammonia tons/yr ..	46,000	94,000		112,000		130,000		83,500	90,000
Urea tons/yr ..	*Nil*	46,000		65,000		65,000		*Nil*	*Nil*
Double Salt tons/yr ..	138,000	200,000		220,000		275,000		250,000	*Nil*
Nangal Salt tons/yr ..	*Nil*	*Nil*		*Nil*		*Nil*		*Nil*	340,000
Location	Bombay	Neyveli	Vijayawada	Neyveli	Vijayawada	Neyveli/	Vijayawada	Itarsi	Nangal
I Cost of Production (Rs. per ton)									
(*a*) Ammonia ..	311·7	308·16	345·2	297·16	334·0	289·36	326·2	360·11	360
(*b*) Urea ..	..	328	358·13	309·76	339·93	305·56	335·43	..	..
(*c*) Double Salt ..	234·2	218·86	247·17	213·70	242·85	207·6	236·56	234·94	..
(*d*) Nangal Salt ..	..	..	..	..	..	..	..	..	162·63
II Capital requirement (Lakhs of Rupees)									
(*a*) Process plants ..	687	1,431	1,431	1,608	1,608	1,798	1,798	1,247	1,510
(*b*) Power plant ..	18	..	76	..	86	..	101	405	..
(*c*) Services including Workshops and laboratories.	42	63	110	77	135	98	163	167	275
(*d*) Lands, offices, roads, and railways.	20	26 ..	26	26	28	28	28	43	55
(*e*) Working Capital ..	30	60	72	68	96	78	106	57	100
(*f*) Colony ..	..	285	292	300	307	315	322	300	250
Total capital required ..	797 or 800	1,865	2,007	2,079	2,260	2,317	2,518	2,219	2,190

13. The figures in the preceding table should be read in the light of the following explanations:

(a) As regards capital costs—

(i) it has been assumed that in Bombay it will not be necessary to build a separate factory colony; consequently no capital expenditure has been provided on this account;

(ii) in so far as a plant at Neyveli is concerned, a basic assumption is that the Lignite Development Scheme will put up the necessary steam and power generation plants and also make arrangements for supply of water. In the light of this assumption no capital expenditure has been provided on account of the services and utilities mentioned above;

(iii) with regard to Vijayawada, it has been assumed that Machkund hydro-electric power will be available for normal factory operations and that a fertiliser unit will have only to instal a small unit for the generation of process steam and by-product power;

(iv) in regard to Itarsi, it has been presumed that a fertiliser unit located there will have to instal a sufficiently large steam-*cum*-power generation plant for the supply of its *full* requirements. It has further been assumed that pending the execution of the Tawa dam project special arrangements will be necessary to ensure security of water supply for which a sum of about *Rs. 90 lakhs has been provided inclusive of the anticipated cost of pumping installations. A sum of *Rs. 20 lakhs has also been provided for the construction of two ten-miles rail links for connecting the factory site and the Pathakhera coal fields with the main railway system. On the other hand, no provision has been made for such additional capital outlay as may be required for opening up the new coal reserves at Pathakhera;

(v) for Nangal, availability of hydro-electric power and of water from the Nangal lake has been assumed; on the other hand, the capital costs include necessary provision for manufacture of heavy water as a co-product;

(vi) for factory colony (except at Bombay) capital provision has been made on the basis of an average Rs. 10,000 per head of the total number of personnel, technical and non-technical, that the unit is likely to employ; and

(vii) the working capital of different units has been calculated to include (1) 3 per cent of the total plant cost for spares, (2) three months' storage of gypsum, (3) two months' sctorage of coal (for units for which coal is one of the raw materials) and (4) for the Nangal plant, six months' production of heavy water.

(b) As regards working costs—

(i) it has been assumed that the double salt plant at Bombay will be based on the utilisation of Saurashtra gypsum and

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* We wish to emphasise that these are rough and tentative estimates. Preparation of reasonably accurate estimates for these items must, for obvious reasons, be preceded by a carefully conducted engineering survey. Attention is invited, in this connection, to our observations on the point in para 3(xii) of Chapter IV.

refinery gas of which the assumed price is Rs. 3/2/- per thousand cu. ft.;

(ii) it has been assumed that a urea-*cum*-double salt plant at Neyveli will utilise local lignite and Trichinopoly gypsum. The price of lignite and the cost of such utilities as water, steam and power etc. have been assumed to be the same as the current estimates of Powell-Duffryn;

(iii) production of urea and double salt at Vijayawada, it has been assumed, will be on the basis of utilisation of Machkund hydro-electric power (of which the assumed price is 6 pies per unit), Singareni coal and Rajasthan gypsum;

(iv) double salt manufacture at Itarsi, it has been presumed will be based on Rajasthan gypsum and Pathakhera coal; and

(v) with regard to Nangal, availability of the necessary quantum of power has been assumed at a rate of 2.6 pies per unit. For production of the recommended type of diluted ammonium nitrate, the cost of clay and chalk delivered to factory site has been assumed to be Rs. 6 and Rs. 10 per ton, respectively.

C—ADMINISTRATIVE

14. *Recruitment and training of technical personnel*—By our terms of reference we are required to make recommendations on, among other points, "the requirements and provision of technical personnel for staffing the new plants". Technical personnel can, we suggest, be conveniently divided in the following three categories:

(1) managerial; (2) supervisory; and (3) skilled workers. The first category can be conveniently subdivided as under:—

(i) Superintendents and equivalent rank;

(ii) Deputy and Assistant Superintendents and equivalent rank; and

(iii) Plant Managers, Plant Engineers and equivalent rank.

Similarly, the second category can be sub-divided as under:

(i) General or Principal Foremen and equivalent rank;

(ii) Foremen and equivalent rank; and

(iii) Assistant Foremen and Chargemen and equivalent rank.

As for the third category*, no subdivision is for our purposes necessary, but we note that in addition to skilled workers, like operators and mechanics and equivalent rank, every unit will require a fairly considerable number of semi-skilled and un-skilled workers whom we have left out of consideration for the time being, because, in the first place, such personnel can hardly be designated with propriety as "technical"; and secondly, the necessary number of workmen coming within this category can, without difficulty, be recruited from among the construction staff engaged on the erection of the recommended plants.

15. For each of the nine plant units, we have estimated the number of technical personnel that will be required for its operation and maintenance under the various categories and sub-categories mentioned in the preceding paragraph. The following table shows at a glance the estimated requirements:

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* We have taken into account only *fully* skilled and trained workers, *i.e.*, first-grade operators, mechanics, etc. Semi-Skilled personnel has been excluded.

TABLE

PERSONAL REQUIREMENTS OF ALTERNATIVE SCHEMES

Plant Capacity (in terms of tons of nitrogen per year)	I	II		III		IV		V	VI
	36,000	72,700		86,500		100,000		65,000	70,000
Location	Bombay	Neyveli	Vijayawada	Neyveli	Vijayawada	Neyveli	Vijayawada	Itarsi	Nangal
I. Managerial Personnel—									
(a) Superintendents and equivalent rank.	3	3	3	3	3	3	3	4	3
(b) Deputy & Assistant Superintendents & equivalent rank.	6	8	9	8	9	9	10	8	8
(c) Plant Managers, Plant Engineers & equivalent rank.	6	10	11	10	11	11	13	10	8
Total Managerial Personnel	15	21	23	21	23	23	26	22	19
II. Supervisory pesonnel									
(a) Principal foremen & equivalent rank.	2	5	5	5	5	5	5	5	5
(b) Foremen and equivalent rank.	14	32	37	32	37	32	37	37	27
(c) Assistant foremen & chargemen and equivalent rank.	56	128	136	128	136	128	136	128	100
Total Supervisory Personnel	72	165	178	165	178	165	178	170	132
III. Skilled workmen— (Operators, mechanics & equivalent rank)	450	700	746	740	786	772	817	713	550
IV. Grand Total of technical personnel of all categories.	537	886	947	925	987	960	1,021	905	701

16. The actual number of men that will have to be recruited in each category and sub-category will depend on such combination of plant units as may be finally approved for installation. The number will naturally vary considerably according as whether it is decided to adhere to the production target specified in our terms of reference or to increase it to some extent. We assume for our present purposes that the number of additional production units will be either (a) two only, *viz.* (i) Nangal (70,000 tons/year nitrogen) and (ii) Neyveli or Vijayawada (100,000 tons/year nitrogen), or (b) three, *viz.* (i) Nangal (70,000 tons/year nitrogen), (ii) Bombay (36,000 tons/year nitrogen), and (iii) Neyveli or Vijayawada (72,700 tons/year nitrogen). On this basis, we estimate that the total requirements of technical personnel in different categories will be as follows:—

Categories of Personnel	(*a*) Two units	(*b*) Three units
I. Managerial—		
(*a*) Superintendents and equivalent rank	6	9
(*b*) Deputy and Assistant Superintendents and equivalent rank	18	23
(*c*) Plant Managers, Plant Engineers and equivalent rank ..	21	25
Total Managerial ..	45	57
II. Supervisory—		
(*a*) General or Principal Foremen and equivalent rank ..	10	12
(*b*) Foremen and equivalent rank	64	78
(*c*) Assistant Foremen and Chargemen and equivalent rank ..	236	292
Total Supervisory ..	310	382
III. Skilled workers (operators, mechanics and equivalent rank) ..	1,367	1,746
Total Technical Personnel ..	1,722	2,185

We would point out that the above table should be considered subject to the minor reservation that while the personnel requirements of the Nangal and Bombay plants are constant numbers, personnel requirements for a plant at Vijayawada will be slightly in excess of the requirements for a plant at Neyveli for the reason that the installation of a relatively small plant for the generation of process steam and by-product power will be necessary at the former location, while all steam and power requirements would be available at Neyveli from the Lignite Development Scheme of which the fertiliser factory will form an integral part. For our present purposes we have ignored this minor difference and, in preparing the above summary statement, have adopted the slightly higher Vijayawada figures.

17. Whether the installation of only two or three units is ultimately decided on for the achievement of the production target set in our terms of reference, recruitment and training of technical personnel for staffing the new plants will be a sizeable job to which adequate attention must be paid as soon as decisions are taken on the capacities and locations of plants. For tackling this problem, we recommend the following measures:

(i) we have suggested in Chapter VII that the Chief Engineer and Production Manager of each Unit should be recruited in advance. All other managerial personnel and supervisory ranks should be recruited within six months of the award of contracts for the construction/commissioning of the related plants;

(ii) the recruitment of skilled workmen (operators, mechanics and equivalent rank) should be deferred till the construction is about to be over. We expect that nearly all the required personnel of this category would be available from among the staff engaged on the construction and erection of the concerned plants; and much would be gained and no sacrifice of quality will be involved if their recruitment is confined to this source;

(iii) for the recruitment of the managerial and supervisory staff of all the units (other than their Chief Engineers and Production Managers) we would recommend that a special recruitment board should be set up as soon as a decision is taken on the number of new units and their capacities and it is possible to determine accurately the number of men to be recruited in each rank of each of these two categories. Though it is clear that the staff of these two categories required for the new plants will have to be largely drawn from trained personnel at Sindri, an effort should be made, by advertisement and offer of reasonably attractive terms, to obtain at least some of the recruits from other chemical and fertilizer plants in India in the private and semi-private sectors and also from the senior and experienced construction staff engaged on the erection/commissioning of the new plants. For the lowest rank of Assistant Foremen and Chargemen, a third source of recruitment will be graduate engineers;

(iv) our recommendation in sub-para (iii) is subject to the proviso that in the senior-most managerial ranks no sacrifice of quality should be contemplated since this is likely to be followed by the most unfortunate consequences. We would accordingly suggest that very strict selections should be made for at least the rank of Superintendents and equivalent positions, (if not indeed for *all* ranks in the managerial category) and there should be no hesitation, if adequately qualified and experienced candidates are not available in India, to recruit foreigners on contracts of not more than five years. All Indian personnel selected for any rank in the managerial category should, we recommend, be sent for a short course of training in one or more selected operating plants abroad by arrangement with the

contractors chosen for the construction/commissioning of the new plants. On their return all such personnel should be required to actively associate themselves with the construction/commissioning of the plants for which they have been recruited;

(v) to the extent that trained personnel may have to be withdrawn from Sindri for the new plants a somewhat difficult situation will arise of which our suggested solution is as follows: We assume that the process of recruitment, as far as Sindri personnel are concerned, would be based largely on promotion to the next higher rank, subject to training and an appropriate period of probation; for example, an experienced Chargeman or Assistant Foreman may be nominated to fill a Foreman's assignment at a new plant or an experienced Foreman may be nominated to fill a General Foreman's or even a Plant Manager's assignment, and so on. To fill the positions vacated by the selected personnel, Sindri will have to allow a series of grade-to-grade promotions; and in the lowest ranks there would thus be a number of vacancies equivalent to the number of personnel selected for the new plants from the Sindri technical staff. The only manner in which this depletion of ranks can be made good is by recruitment of the necessary number of graduate engineers (preference being always given to those having some industrial, preferably operational, experience) and by putting the new recruits through an intensive special course of training for a minimum period of one year. In the interest of Sindri we would suggest that Sindri should not be required to release any personnel selected for the new plants until the recruitment and intensive training of the graduate engineers required to fill the depleted ranks in Sindri is completed. This task of recruitment for anticipated vacancies in Sindri may, we suggest, be quite appropriately assigned to the special recruitment board, the establishment of which we have suggested in para (iii) above. We have made no attempt at this stage to estimate the number of fresh graduate engineers that it will be necessary to recruit for filling anticipated vacancies at Sindri, since the number will depend upon the number of recruits available from the other sources mentioned in para (iii);

(vi) it is clear that a special training programme will have to be arranged at Sindri (a) for such partially trained personnel as may be recruited for the new plants either from Sindri or from elsewhere and (b) for fresh engineering graduates recruited to fill anticipated vacancies in the Sindri technical staff and also to some extent vacancies in the lowest rank of supervisory personnel for the new units. Since in another two years or so Sindri will have a urea as well as a double salt plant (and the latter plant will include nitric acid and ammonium nitrate units) there should be no difficulty in giving the necessary practical training to recruits selected to fill supervisory assignments in the new plants. For all such personnel the period of

training should be between one and two years depending on the amount of practical experience which they may already possess. A similar period of intensive training may be laid down for personnel recruited to fill anticipated vacancies in the Sindri technical organisation. It is in any case clear that considerable expansion of the facilities which exist at Sindri for the training of graduate apprentices will be necessary for a period of two to three years and this is the first point which, we suggest, should be settled at an early date in consultation with the Sindri management.

18. *Transportation arrangements*—We have considered the question of transportation arrangements both from the angle of (a) facilities required during the period of construction of the new plants and (b) their operational requirements. A general recommendation which we would make in the light of our discussion with the Railway authorities is that early steps should be taken for the electrification of the Bhusaval—Igatpuri section of the Western Railway and (whether or not one of the new plant units is located at Vijayawada) for the stepping up of the present capacity of the Vijayawada—Madras section of the Southern Railway by, for example, doubling the entire line and/or by converting the metre gauge section between Gudur and Renigunta into broad gauge. We do not suggest that these are absolutely immediate requirements but we hope that early steps would be taken for the removal of these standing bottlenecks on the railway transportation system as soon as funds and technical resources permit. These improvements, we suggest, are necessary to ensure not merely satisfactory operation of fertiliser plants and reasonably quick movement of their end-products as well as the raw materials required for their operation but, generally, reasonably good traffic facilities in the West and the South.

19. Apart from the above, our specific suggestions in the context of the particular locations we have recommended are as follows:

(i) in case one of the new production units is located at Neyveli, arrangements should be taken in hand for provision of additional railway sidings at Ariyalur which is the rail head for Trichinopoly gypsum. We would also suggest that Neyveli should, at the earliest possible date, be connected with the broad gauge system from the nearest point, in order that break-of-gauge transhipment may be avoided for sending out the end-products of the Neyveli factory to areas served by the broad gauge system. We do not apprehend that during the period of construction any difficulty would arise in bringing to the site imported plant and machinery since adequate road communications are available both from Cuddalore port as well as from Madras. It would thus be possible to transport by road any oversize plant and machinery which it may not be possible to transport by metre-gauge railway;

(ii) as already indicated, the location of a plant in the neighbourhood of Itarsi will involve provision of two railway links, each about ten miles long, for giving connection to the factory site and the Pathakhera coal fields. For assembling stores, materials, plant and machinery at the factory

site during the period of construction, a short rail-link will have to be established for connecting the site with a convenient point on the Bombay-Calcutta line. After the factory goes into operation, the link will be useful for bringing in gypsum and sending out end-products;

(iii) in case a factory is located at Vijayawada, the proposal which is now under consideration for abolishing its connection with the metre gauge system should, we recommend, be abandoned. We would recommend further that consideration should be given to the early provision of an additional railway bridge on the Krishna. If, on further investigation, it is decided that the Vijayawada factory should be sited on the right bank of the Krishna, the provision of a short metre gauge and/or short broad gauge siding will be necessary;

(iv) no special measures appear to be necessary in the context of our proposals for the installation of new plants at Bombay or at Nangal.

20. We have made no attempt to calculate at this stage whether and if so to what extent the installation of the new plants would require provision of additional wagons for transportation of raw materials and end-products nor how it would affect the existing goods traffic movements. Our report contains, we believe, full data and materials on the basis of which the necessary calculations can be easily made once decisions are taken on the issue of location of the new plants and their capacities. We suggest that immediately these decisions are taken, the Railway authorities should be duly notified of them and requested to set in train the provision of whatever facilities may be required for their satisfactory and timely implementation.

21. *Development of mines*—An administrative measure which will require early attention is the development of some of the gypsum and coal mines which it will be expedient, for economic and other reasons, to utilise for the new plants. For a double salt factory at Neyveli it would be necessary to draw on the Trichinopoly gypsum reserves and similarly for a double salt factory at Bombay exploitation of the Saurashtra gypsum reserves will be expedient. Taking all factors into consideration, we suggest that a Central Gypsum Development organisation should be established with headquarters at Jodhpur/Bikaner and branch organisations at Trichinopoly and at Virpur/Ran/Bhatia in Saurashtra. Since the proper development of the Saurashtra and Trichinopoly gypsum mines will be absolutely essential, we suggest for consideration that Government (or the Fertiliser Board whose establishment we have recommended in Chapter VII) should, if possible, take a lease of the entire reserves at both the places and organise systematic mining in accordance with up to date modern mining methods. The possibility of an early termination of all existing leases, particularly in respect of the Trichinopoly mines, should, we suggest, be examined. Similarly, the management of any factory that may be located at Itarsi should take a lease of the Pathakhera coal reserves from the Madhya Pradesh Government and, in advance of the installation of the factory, take suitable steps to open up the reserves and set up an organisation for mining the coal according to requirements.

CHAPTER VII—MODE OF IMPLEMENTATION OF RECOMMENDATIONS

The Sindri plant was built under two general contracts, one with a firm of Consulting Engineers and the other with a firm of "Constructors" who selected contractors for different sections of the job, co-ordinated and supervised their work and generally functioned as the Agents of the Government of India. Contracts for the Sindri Coke Oven Plant and the new expansion scheme now under execution were, on the other hand, awarded on the basis of turn-key jobs. The designing and construction of the related works as well as their commissioning became under this arrangement the undivided responsibility of the selected contractor, the responsibility of the Sindri Management being restricted solely to making available the work site and construction facilities and to paying the contract price in instalments according to a mutually agreed schedule.

2. We are convinced that for any new factory, however large it may be, it is unnecessary at the present juncture to appoint a firm of Constructors as Government's general agents charged with the task of arranging for contractors and supervising and co-ordinating their work. We are equally convinced that it would be unfortunate to award contracts on the basis of turn-key jobs which may ensure satisfactory enough plants but would not (i) be the most economical or the most convenient arrangement; nor (ii) what is more important, add to indigenous experience or advance indigenous knowledge. We have come to the conclusion that while it will be necessary, even on the present occasion, to depend largely on imported technique and know-how for designing the new plants, on imported plant, equipment and machinery for their construction at site and, to some extent, on imported technicians for supervising their assembly and commissioning, our contractual arrangements with the selected foreign firms should be so devised as to secure full association of Indian technical personnel at every stage of the work and also full utilisation, as well as maximum development, of whatever construction and fabrication facilities exist in the country today.

3. In the context of the above conclusion, we have considered the expediency of appointment of one or more firms of Consulting Engineers for the new production units; and our considered view on the point is that though in the present circumstances some association with one or more specialist firms may be necessary for strictly limited purposes, the full-scale engagement of Technical Consultants (on the lines on which Messrs Chemical Construction Corporation of New York were engaged for the Sindri plant) is not essential and should not be contemplated except for the Nangal plant. The technique of making heavy water is new and uncommon and its knowledge is, we understand, confined to only a handful of firms in the world. We consider in the circumstances that it would be expedient to engage, on the best possible terms, the services of one of them for technical guidance in the designing, construction and commissioning of the heavy water plant from start to finish. In theory it is possible to engage a firm of technical consultants only for the "heavy water sections" of the combined plant, that is, up to but not including the

stage of ammonia synthesis; but on practical considerations it would, we feel, be best and ultimately more economical to associate, subject to the restrictions and stipulations mentioned below, the selected firm with the entire project covering both the heavy water and the fertiliser sections.

4. Before explaining our plan for the execution of the other projects which are purely fertiliser production units, we would take the liberty of making a digression in order to discuss in some detail a topic with which our plan is vitally connected and which forms in a way an integral part of it. In considering the issue of the best mode of carrying out the approved projects, we have been impressed by the need for and importance of pooling and centralising the technical and administrative resources that will be at Government's command on the execution of the current scheme of indigenous production of chemical fertilisers. Much of the potentiality of the State-owned fertiliser projects will, we feel, be lost if they are regarded in future as separate entities and each is managed by a different Board and allowed to develop its own individual standards and traditions with only a loose type of co-ordination at the level of the Ministry. In order that the most can be made of their resources, it is, in our considered view, essential that all of them, old and new, should be fully integrated and administered as a well-knit joint endeavour under common direction and control. We advocate accordingly, as the very first step in the process of implementation of our recommendations, the setting up of a common Fertiliser Board to administer and control all State-owned fertilizer production units including Sindri. In the following four paragraphs we proceed to elaborate the advantages that we think will follow upon the establishment of a common Fertilizer Board, the manner in which that Board should be constituted and the functions and responsibilities with which it should be vested.

5. While the common Board must have a body of common Directors, whole-time and part-time, it may, we recognise, be necessary to devise a system of appointing Associate Directors for individual projects. In the case of the Nangal Plant, for example, it may be considered expedient to have on the Board a representative of the Atomic Energy Commission and/or a representative of the Bhakra Control Board; these representatives cannot for obvious reasons be accepted as common Directors for all projects and should therefore be given a distinctive designation so that they may exercise their powers and fulfill their responsibilities only in relation to the particular project for which they may be specifically named. With this exception, all Directors, whole-time or part-time, paid or un-paid, should exercise concurrent jurisdiction over all projects placed under the administrative control of the common Board and a single company should be registered* in respect of all of them. There should, we suggest, be a paid whole-time executive Chairman for the common Board and not a Chairman for only presiding at meetings as currently provided by

* This will involve the winding up of the Sindri Fertilizers and Chemicals Ltd. which should present no technical difficulty. The new omnibus company might, we suggest, be appropriately registered as Hindustan Fertilizers and Chemicals Ltd. and all properties in all State-owned fertilizer production units vested in it.

the Articles of Association of Sindri and other State-owned industrial concerns. If, however, it is preferred to retain the status, functions and responsibilities of the Chairman as they are at present and continue to nominate a part-time incumbent to fill this office, the Board should have, alternatively, a paid whole-time Managing Director as its chief executive. With a whole-time executive Chairman, there should be as many Managing Directors as there are production units. With a single whole-time Managing Director each factory should have a General Manager, all the General Managers being also Directors of the Common Board. The Technical Chief of each production unit should also, we suggest, be nominated as a Director of the common Board unless he is the Managing Director/General Manager of the unit. Other interests may be represented on the Board more or less in conformity with the present practice except that we suggest that none should be nominated as a part-time Director unless he is in a position, by reason of his knowledge and experience, to make some definite contribution in a particular line and care should be taken to avoid, as far as possible, duplication of representation of the same or similar interests.

6. Under the new set-up which we visualise the core of the common directing and controlling Board will consist of the whole-time paid members, that is—

(i) the chief executive, whatever may be his designation;

(ii) the administrative heads of individual units, whatever again, may be their designation; and

(iii) their technical chiefs.

The success of all production units placed under the charge of the common Board will, to a large extent, be the joint responsibility of this body of men, the one single individual more particularly responsible being, of course, the chief executive. Since these men will be on the Directorate, they will have the required status, powers and authority commensurate with their responsibility; and, generally, the set-up will conform to the Indian Fertilizer Mission's view* that there should be no "divorce of responsibility from power and authority at any level". Care should be taken to ensure that the Board as a whole functions in the main as a policy Board and does not get involved in too many details of day to day management. It will, of course, be the supreme supervisory and controlling authority competent to revise, at its sole discretion, the decisions taken by all subordinate authorities at all levels in exercise of their delegated powers. Normally, however, its main tasks would be to lay down decisions on matters of broad policy, to secure uniformity of action on all matters of importance and, generally, to enforce co-ordination in all spheres. Details of day-to-day management should, we suggest, be normally left to a high powered Committee of Management for each individual production unit which should be a statutory body enjoined by the Articles of Association of the Company. The Committee of Management for each factory should consist of—

(i) the General Manager or the Managing Director;

(ii) the Technical Chief unless he is also the General Manager/Managing Director;

* Para 47 of the Mission's report.

(iii) the Chief Engineer and the Production Manager; if one of them is also the Technical Chief then only the other;

(iv) the Commercial and Accounts Chief; and

(v) the Personnel Chief.

To the Management Committee for each factory fairly wide powers should be delegated by the Board; in addition, restricted delegations should be made to the General Manager or Managing Director himself with powers to sub-delegate his authority to any of his principal lieutenants individually. Since in the last analysis, there cannot be more than one Captain in a ship, it will be necessary to provide, in the form of a statutory rule or otherwise, that in case of any difference of opinion between the General Manager/Managing Director and his colleagues on the Committee of Management, the former will have the authority to take action in his discretion in accordance with his own view even though he may be in a minority of one, subject, however, to his reporting his action in all such cases to the Fertilizer Board. The constitution of a Committee of Management on these lines for each production unit will achieve a two-fold objective: (i) it will indicate the group of individuals primarily responsible, jointly and individually, for the efficient management of the unit and will vest them with commensurate authority; and (ii) it will imbue them with a high sense of responsibility and serve as an incentive to give of their best for the success of the concern.

7. It is our opinion that the establishment of a common Fertilizer Board on the lines indicated above will be the best way of ensuring co-ordination and concerted action in every sphere as between different State-owned fertiliser production units, widely distributed all over the country. The unification of control which we visualise will not only ensure quick and co-ordinated planning and execution of projects, achievement of satisfactory production levels at all centres and expeditious investigation and solution of all engineering problems, but also render possible the establishment of centralised fabrication facilities, a central drawing and designing office, a central Technological Research and Development Bureau where new processes and techniques can be experimented with and perfected, a central marketing organisation, etc. etc. Further, the constitution of a central authority controlling all State-owned fertilizer production units will facilitate all-round practical training of technical personnel in various types of plants and processes and free exchange of personnel as between different production units so as to ensure that the right man is always available for the right job at the right time. In brief, the establishment of the common Board will, in our view, be the most effective way of turning to the best account the technical resources of State-owned fertilizer units; of ensuring that opportunity is taken of the current expansion programme to advance chemical engineering technology in India, perhaps to an extent which will enable Indian technicians to evolve and perfect processes and techniques of their own which India in due course may sell to other countries abroad. It should, at any rate, be possible, assuming the development of human and material resources that can be very reasonably expected under the auspices of a Central Board, to "Indianise" our next construction endeavour; in other words, to

implement our next programme of expansion of indigenous production of chemical fertilisers at least largely, if not wholly, with Indian materials, with plant and equipment of Indian make and under the supervision of qualified and knowledgeable Indian personnel. That these are not vain expectations will be realised if it is borne in mind that the resources which will be at the command of the Indian Fertilizer Board even at the end of the current expansion programme will be comparable, in many cases favourably, with those of leading firms of international reputation in the field of chemical industry.

8. A possible criticism of the plan of establishing a Central Fertilizer Board is that the number of production units in its charge will be so many and it will have so many matters to deal with that its tasks will be unwieldy for the due performance of which it may have to be in almost continuous session. That, in turn, will mean that no part-time Director would consent to be a member of it or even if he does, would find time to attend all its meetings. We have considered this criticism but do not accept it. If as we visualise, the Board functions mainly as a policy Board, if local Committees of Management are set up for individual units and are vested with reasonably wide powers, and if, again, the chief executive of the Board is empowered at his level to take decisions on minor issues, and even on matters of comparative importance subject to his reporting them to the Board, we do not see why it should be necessary for the Fertilizer Board to meet more than once a month nor why any particular meeting should last for more than a day at the outside. Apart from the delegations mentioned above, the Board would no doubt find it convenient to function in many matters through committees consisting of some of the whole-time paid Directors; the Board might also conveniently set up a general committee of *all* whole-time paid Directors including the chief executive and delegate to it many of its less important functions. These are some of the many ways in which the business of the common Board can be conveniently and expeditiously conducted; and if some of these expedients are adopted, the Board may not ultimately find it necessary to meet more than one in two or even three months to dispose of the residual business which will then entirely consist of important questions of policy pertaining to the various projects under its control.

9. On the assumption that our recommendation for the creation of a Central Fertilizer Board will be accepted and implemented without delay, we can now explain the details of the procedure we would suggest for the execution of the approved projects:

(a) As the very first step we would recommend immediate recruitment of the following four senior officials for each approved factory including Nangal plant:

- (i) the Administrative head, *i.e.*, the General Manager/Managing Director;
- (ii) a fully qualified Chief Engineer; there should be no hesitation in recruiting a foreigner to this post if no qualified and experienced Indian national is available for the office;
- (iii) a qualified and experienced Production Manager of proved merit and having the requisite operational and adminis-

trative experience; we expect that there are at least some technicians in the country, at Sindri or elsewhere, who would come up to expectations; for the rest, recruitment from abroad may have to be resorted to; and

(iv) a Chief Accounts Officer.

It would, we suggest, be a grave blunder to take the view that these important top-ranking posts can be created and filled at a later stage and some money can thereby be saved. Whether a firm of Consulting Engineers is appointed for a project or not—but more so in a case where the full-scale engagement of a firm of Technical Consultants is not contemplated—the immediate organisation of the proposed team at each new production centre is, in our view, a *sine qua non* if it is desired that no avoidable delays should occur in the implementation of any decision and responsibility for progressing the approved projects with expedition should be placed squarely on the right shoulders. We are deeply convinced that any postponement of these appointments would mean no saving, but, on the other hand, involve unduly expensive delays in the end. We suggest accordingly that steps should be taken for the recruitment of this key personnel even while arrangements are in hand for the creation of the Central Fertiliser Board. We suggest also that in all cases where it is clear that nationals of other countries will have to be recruited, the recruitment should be done by negotiations or personal contacts and not by the dilatory process of advertisement through Missions, which has in the past hardly ever brought about satisfactory results; and further that for every foreign technician recruited from abroad, two qualified Indian under-studies should be appointed forthwith in order that the former can be replaced in the shortest possible time.

(b) Simultaneously two foreign experts should be engaged on short-term contracts (not more than three years) to fill the position of consultants and technical advisers without any executive authority. These experts should be direct employees of the Central Fertilizer Board and not attached to any particular factory. Apart from high academic qualifications, the experts should possess firsthand experience, of not less than 7 years, of the technique of urea and double salt production. In addition, they should be capable organisers and have intimate experience in designing chemical plants. It would be expedient to recruit for Nangal a similar expert on heavy water technique who should also be a direct employee of the Central Fertilizer Board. The services of these consultants would be necessary only so long as the new plants are not fully commissioned and brought to a satisfactory state of production. Their selection and recruitment, we realise, will be a matter of some difficulty; we suggest, therefore, that there should be no hesitation in offering specially attractive terms to prospective candidates having the requisite qualifications. In considering these terms it should be borne in mind that the engagement of a consultant, who is no real expert, would be worse than useless and that no good man would accept a temporary assignment unless the terms are highly attractive and, moreover, some assurance is forthcoming of his being able to return to his own job or a better job at the end of his Indian tenure. In our opinion, the type of men we have in mind can be recruited only in one way, namely, by a direct approach to the foreign Governments who are interested in, and are genuinely anxious to help, the

industrialisation of India coupled simultaneously with an approach to friendly firms with whom we have already developed business contacts.

(c) After the recruitments we have recommended in (a) and (b) are made, a Standing Technical Committee should be set up consisting of

(i) the three foreign experts or consultants;

(ii) the Chief Engineers of the new production units;

(iii) their Production Managers; and

(iv) two or three technicians of experience drawn from Sindri or elsewhere including firms in the private sector.

Our recommendation is that this Standing Committee should to a large extent fulfil the functions of Consulting Engineers for the new production units and their jurisdiction should also cover Nangal to a limited extent. The Committee should endure so long as all the new production units are not fully erected, organised and commissioned; and it should function under the general guidance and control of the Central Fertilizer Board which, we expect, would be established by the time the key personnel are recruited and it is possible to set up the Committee.

(d) The first task of the Standing Technical Committee should be to prepare a lay-out design of the new plants with necessary drawings for the approval of the Central Fertilizer Board; and thereafter to prepare specifications for each plant on the basis of the approved designs. In the case of the Nangal plant the plant designs will have to be made and specifications prepared by the Consulting Engineers in consultation with the Standing Technical Committee and under their general instructions. In the case of all other plants the primary responsibility for the preparation of designs/drawings/specifications will devolve on the Standing Technical Committee and it will be for that Committee to decide whether and if so to what extent and in what respects the association of foreign firms should be enlisted. We recognise that it may not be possible to eliminate completely the help of one or more foreign firms, particularly at the designing stage; in the first place, no experience whatsoever is available in the country today for the preparation of detailed designs of complicated plants and processes; and secondly, no experts, however experienced and knowledgeable they may be individually, can be an adequate substitute for an organised firm with its accumulated experience and store-house of traditional knowledge. Should for these reasons the Standing Technical Committee consider it necessary to associate with their work one or more specialist firms abroad, we suggest that the association should be permitted subject, however, to the following conditions:

(i) the association should be for strictly limited and clearly defined purposes;

(ii) the specified "purposes" should not, in any case, include supervision of plant construction or of commissioning of plants;

(iii) the associated firm should be required to carry out the tasks allotted to it as far as possible in India with the

help of Indian personnel recruited for the purpose by the Fertilizer Board; and even in regard to such portion of its work as has necessarily to be done at its headquarters abroad, it should permit collaboration of Indian technicians to be specially deputed for the purpose; and finally,

(iv) it should be distinctly understood that whether one or more foreign specialist firms are associated in the limited manner indicated above or not, the Standing Technical Committee will remain ultimately responsible for all designs, drawings, estimates, specifications as well as for co-ordination of construction, its general supervision and finally the commissioning of the erected plants. It follows that to enable the Standing Technical Committee to discharge its responsibilities in all these matters, the Central Fertilizer Board should recruit, on the advice of the Committee, an adequate number of qualified and experienced design engineers, estimators, draughtsmen and place their services at the Committee's disposal. If this should be found necessary, a few qualified design engineers should be recruited from abroad.

(e) On the basis of the specifications drawn up by the Committee the Central Fertilizer Board should invite tenders *for each section of each plant* including the group of plants approved for Nangal. When tenders are received, they should be scrutinised by the Standing Committee and the final selection of contractors should be made by the Central Fertilizer Board on the Committee's advice; and thereafter contracts should be awarded for supply and erection of individual plants or groups of plants. Whether a purely supply contract or a supply-*cum*-erection contract should be awarded in any particular case, should be determined by the Committee on its merits. In certain cases it might indeed be necessary to extend the scope of the contract to cover not only supply and erection but commissioning as well by the contractor's own personnel. In many other cases on the other hand, a purely supply contract may be considered enough, erection, assembly and commissioning being then the responsibility of the local factory organisation. For each individual contract many details will have of course to be settled, such as delivery schedule, prices, guarantees, penalties, etc. and all this should be the business of the Standing Committee subject of course to the general control of the Central Fertilizer Board. The same procedure should be followed for the Nangal plant except that all technical advice will be tendered by the selected firm of Consulting Engineers through the Standing Technical Committee.

10. It is obvious that in addition to an adequate central organisation at the headquarters of the Fertilizer Board, of which two important constituents* will be (a) a fairly large designing, drawing and estimating office and (b) a central technological bureau, it will be necessary for each individual production unit to have a strong local organi-

* Please see in this connection, paras 7-8 of Chapter VIII. We visualise that at the end of the construction of the new plants, all accumulated data and knowledge in the matter of both technique, know-how and processes as well as designs, drawings and estimates should be left with these two central organisations which must of course function in closest association with each other.

sation. A great many tasks of considerable magnitude and importance, both purely technical as well as technical-*cum*-administrative, will devolve on the local organisation. In the purely technical sphere, for instance, the local organisation will have to:

(i) carry out the directions of the Standing Technical Committee;

(ii) co-ordinate the work of different contractors and afford them facilities stipulated by their contracts;

(iii) supervise the construction of different sections by the concerned contractors;

(iv) arrange for assembly and erection of all such plant and machinery for which only supply contracts may be approved;

(v) arrange for such alterations in the approved designs as may be considered expedient from time to time and correction of such designing errors as may come to light with the progress of the work;

(vi) arrange for the commissioning of plants, after completion of erection, and demonstration runs, etc. etc.

Similarly, in the technical-*cum*-administrative sphere the organisation will have to tackle such problems as

(i) acquisition of land and construction of townships inclusive of markets, schools, hospitals, etc.;

(ii) arrangements for sanitation and medical aid;

(iii) solution of labour problems and disputes;

(iv) procurement of raw materials;

(v) provision of railway connections as also road communications;

(vi) solution of transportation problems, particularly for bringing to work site out-of-gauge plant and machinery;

(vii) provision of temporary accommodation for both personnel and valuable machinery and equipment;

(viii) provision of utilities required both during construction and operation, particularly water, power and steam;

(ix) recruitment of subordinate personnel, technical and non-technical, and their training;

(x) construction and equipment of workshops and laboratories;

(xi) acquisition of tools, tackles, plant, machinery particularly earth-moving machinery; establishment of an efficient purchase and stores organisation;

(xii) arrangements for disposal by sale or otherwise, of by-products and waste products;

(xiii) securing of import licences;

(xiv) due payment of contractors according to agreed schedules; and

(xv) generally all such measures as may be necessary for the orderly, smooth and expeditious execution of the approved project.

11. We have tried to set out in some detail the fairly formidable task which will confront the local organisation with a view to emphasize firstly the need for setting up the organisation at the earliest possible date and secondly, the absolute necessity of making it as strong, efficient and business-like as possible. The nucleus of the local organisation will be provided by the four senior officials whose immediate recruitment we have recommended in paragraph 9(a). It will be for them to set up, under the supervision of the Central Fertilizer Board and its chief executive, an adequate organisation at each centre, but an essential pre-requisite for the success of their efforts is adequate delegation of powers, particularly powers of recruitment and powers of financial sanction. These powers can be initially delegated to the General Manager alone or better still perhaps, the Committee of Management we have recommended in paragraphs 6 may be set up even to start with and vested with fairly wide powers, delegations on a more restricted scale being made to the General Manager. We would be going far beyond qur province if we were to make any attempt to indicate in any detail the type of organisation which we think would be suitable at each individual centre; but, generally speaking, it would be expedient for each local organisation to establish, to begin with, all departments necessary for the normal functioning of the factory after it is erected and commissioned.

12. The help of consulting engineers would be available at Nangal for the supply of technique and know-how, the preparation of designs and specifications, the scrutiny of tenders and selection of contractors, supervision of construction and initial commissioning of plants. The Nangal organisation need not, therefore, be quite so elaborate as the organisation that it will be necessary to set up at other centres.

13. We have considered the possible criticism that the contemplated substitution of a firm of foreign Consulting Engineers engaged on a fee by the proposed Standing Technical Committee would be (i) more expensive; (ii) more troublesome; (iii) more dilatory, and (iv) less efficient. We wish to point out, however, that to engage. on the usual basis, a firm of consulting engineers and vest it with full responsibility for the entire job from start to finish is to play safe; it is *the* one way of making sure that the job is done at least with a moderate degree of efficiency and the least amount of trouble. Our objection to the engagement of consulting engineers is, however, twofold; the main objection is that the procedure would leave no residual knowledge behind and no accumulation of useful and valuable experience; we would remain at the end of the job precisely where we were at its beginning. The other objection is that no firm of consulting engineers can be expected to be completely devoid of bias; to put it frankly, the selection of any particular firm of consulting engineers would mean to a large extent virtual pre-selection of the main construction firms for doing the job; and these firms, apart from all considerations of economy, may not be the very best firms for doing it. We do not consider that the procedure we have recommended involves taking any unreasonable risks. Provided our resources, human and material, are pooled and organised and their potentialities are thus maximised under the unified control of a single Fertilizer Board, we don't think that the procedure we visualise would be, even relatively, inefficient. Nor do we believe that it will ultimately be any less economical than the full-scale engagement of

an expensive firm of technical consultants. True, the procedure we recommend will involve taking a great deal of trouble but considering the ultimate gain in the shape of acquisition of practical experience, the trouble would, we suggest, be fully worthwhile. And if, again, it takes a slightly longer time than a more orthodox procedure, the possible (though by no means certain) delay of a few weeks or months would be more than counterbalanced by moral and material gains. After a very anxious consideration of all factors we remain convinced that the course of action we have recommended would be the wisest and most expedient in the circumstances of today.

14. We recognise that some time is bound to elapse before the top officials of the various production units can be recruited and it is possible to establish the Central Fertilizer Board. There should, we recognize, be no period of inaction, complete or partial, once Government take definite decisions on the number and location of the new fertilizer production units and accord financial sanctions. For interim measures to be taken immediately after decisions are taken on our recommendations, we have considered two possible alternatives:

(a) appointment of an *ad hoc* committee with a whole time Chairman; and

(b) appointment of a whole-time Special Officer functioning directly under Government with at least three competent lieutenants of appropriate rank, technical and non-technical.

After giving the matter due consideration we are inclined to the view that the second alternative would be preferable and produce quicker and more satisfactory results because what would be required at this stage is executive action and not study and investigation of technical or administrative problems. Whether, however, an *ad hoc* committee is appointed or it is preferred to appoint a Special Officer (who must be invested with necessary status and powers so that he can function effectively) the duties of the committee or the officer, as the case may be, should be laid down as follows:

(i) to take immediate measures for the creation of a Central Fertilizer Board;

(ii) in consultation with appropriate authorities, particularly the concerned State Governments, to take preliminary measures

(a) for land acquisition at selected locations;

(b) for water and power supply;

(c) for sorting out transportation problems during construction including problems connected with the transportation of raw materials; and

(d) for location and reservation of sources of raw materials;

(iii) to take measures for the early recruitment of

(a) 4 senior officials for each production unit;

(b) three fully qualified and experienced technical consultants; and

(c) a nucleus staff of subordinate technicians of the rank of technologists, design engineers, estimators, draughtsmen;

(iv) to select,* subject to the approval of Government, a suitable firm of Consulting Engineers for Nangal;

(v) to prepare and submit a phased estimate of expenditure;

(vi) to set in train arrangements for the training of technical personnel to the extent that such arrangements can be made in the country; and

(vii) to take such other measures as may be required for the expeditious implementation of the recommendations of this committee to the extent that they are accepted by Government.

The assignment indicated above should not take more than about two to three months to complete and whether the assignment is given to a Special Officer or to an *ad hoc* committee, the authority should be *functus officio* immediately the Central Fertilizer Board is set up and its chief executive is selected. All matters included in the above "terms of reference" should thence onwards be the responsibility of the Fertilizer Board.

15. To summarise, our recommendations, stripped of details, briefly are:

(i) A Central Fertilizer Board should be brought into existence as early as possible and all State-owned fertilizer units, old and new, should be placed under its administrative control.

(ii) Immediate steps should be taken for the recruitment of the following personnel:

(a) for the Central Fertilizer Board, a whole-time executive Chairman, alternatively, a whole-time Managing Director;

(b) for each individual production unit, a General Manager or Managing Director, a Chief Engineer, a Production Manager and a Chief Accounts Officer; and

(c) two foreign experts on urea and double salt technique having extensive experience in designing chemical plants; and also a third expert on heavy water technique for Nangal, all the three experts being engaged on short term contracts and made directly answerable to the Central Fertilizer Board.

(iii) On the Central Fertilizer Board should be nominated as *ex-officio* Directors the administrative and technical heads of all individual production units.

(iv) For each individual production unit a statutory Committee of Management should be set up consisting of

(a) the General Manager/Managing Director,

(b) the Technical Chief,

(c) the Chief Engineer and the Production Manager,

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* We understand that this task, among others, has been entrusted to a recently constituted Technical Committee.

(d) the Commercial and Accounts Chief, and

(e) the Personnel Chief.

(v) As soon as the recruitment of the personnel mentioned in (ii) is completed, a Standing Technical Committee should be set up consisting of

(a) the 3 experts recruited from abroad on short term contracts;

(b) the Chief Engineers and Production Managers of individual units; and

(c) in addition, 2 or 3 experienced technicians drawn from Sindri or elsewhere.

(vi) This Standing Committee should be required to fulfil to large extent the functions of consulting engineers in respect of all the new production units except Nangal. The first task of the committee would be to prepare designs. drawings, estimates of the new plants and thereafter draw up specifications for each plant. If, for the due performance of this and other tasks, the committee should desire to secure the association of one or more foreign specialist firms, it should be permitted to do so for strictly limited and clearly defined purposes and on the understanding that the engagement of any such firm will in no way detract from the overall responsibilities of the committee.

(vii) For Nangal, a firm of consulting engineers having special experience in designing and building heavy water plants should be engaged and required to function in close collaboration with, and under the supervisory control of, the Standing Technical Committee.

(viii) On the basis of the specifications prepared by the Standing Technical Committee (in the case of Nangal by the consulting engineers under the supervision of the Standing Technical Committee) tenders should be invited *for each section of each plant.* After the tenders received are scrutinised by the Standing Technical Committee (in the case of Nangal by the Consulting Engineers under the supervision of the Standing Technical Committee) contracts should be awarded for individual plants or groups of plants, not on the basis of turn-key jobs, but on the basis of either supply of plant and equipment alone or their supply and erection or, in exceptional cases, their supply, erection and commissioning.

(ix) Adequate local organisations for individual production units as well as a headquarters central organisation for the Central Fertiliser Board should be built up as early as possible.

(x) As an interim measure the processing of the programme visualised above should be entrusted to either a small *ad hoc* committee or preferably a Special Officer invested with the necessary status and powers and assisted by competent lieutenants of appropriate rank.

CHAPTER VIII—MISCELLANEOUS

In this Chapter, we propose to deal with certain matters which we could not appropriately discuss in the foregoing portion of our report, chiefly because despite their inherent importance and also their intimate connection with our investigations, they are, strictly speaking, outside our terms of reference.

(1) POSSIBLE LOCATIONS OF PLANTS FOR THE MANUFACTURE OF ALTERNATIVE FERTILIZERS

2. In the course of our review of State Governments' proposals we have drawn attention at appropriate places to certain locations where we think the manufacture of nitro-limestone can be established economically. In paragraph 12(a) of Chapter II we have suggested that experimental investigations should be taken in hand with a view to achieve a type of specially treated product which would successfully withstand conditions of high humidity associated with high temperature so that it can be accepted as a suitable fertiliser for acid soils in the south and the east. If as a result of these experiments a suitable type of nitro-limestone can be evolved, we suggest that its manufacture may be considered at one or other of the following places, all of which have the advantage of nearness to sources of the main raw materials:

(i) Bhadravati in Mysore;
(ii) Vijayawada in Andhra;
(iii) Rourkela in Orissa;
(iv) Durgapur in West Bengal;
(v) Gauhati-Pandu in Assam;
(vi) Barkakana in Chotanagpur, Bihar;
(vii) Haidernagar near Japla Cement Factory in the Son Valley in Bihar;
(viii) Mirzapur in Uttar Pradesh; and
(ix) Ramagundam in Hyderabad.

We are inclined to omit from the above list, for the time being, Gauhati-Pandu in Assam chiefly because of the great transportation difficulties in this area not only from the point of view of despatch of end-products to distant destinations all over India but even from the point of view of assembling the necessary raw materials at the work-site. Until communication facilities are developed in the State, the cost of transportation over even short distances across high mountain ranges and deep valleys will remain so high as to eliminate all possibility of economic production of almost any type of fertiliser.

3. With regard to the eight other locations mentioned above we have roughly calculated that the production cost of nitro-limestone

in a plant designed to produce 50,000 tons of nitrogen per year will amount to as follows:—

Location.	*Production cost per ton in rupees*
(1) Bhadravati	158
(2) Vijayawada	167
(3) Rourkela	142
(4) Durgapur	163
(5) Barkakana	167
(6) Haidernagar	168
(7) Mirzapur	156
(8) Ramagundam	174

Some of the important assumptions on which our calculations are based are as follows:

(i) in the case of Bhadravati, we have assumed availability of cheap hydro-electric power (on the completion of the Honnemaradu scheme) at the rate of 2* pies per unit; it has been assumed that ammonia will be made by the electrolytic process;

(ii) in the case of Rourkela, the availability of the hydrogen content of the steel plant coke oven gas has ben assumed; and the hydrogen has been priced at 8.75 annas per 1,000 cu. ft. on the basis of its heat value as compared with the heat value of total coke oven gas of which the assumed price is Re. 1/- per thousand cu. ft.

(iii) the cost calculations for Mirzapur have been made on the basis of utilisation of Bihar coal for the time being (to be replaced in due course by coal from the Singhrauli coal fields after these fields are† developed) and the availability of Rihand dam power at the rate of 4 pies per unit;

(iv) in the case of Vijayawada, Durgapur and Ramagundam, cost of production of ammonia has been calculated on the basis indicated in Chapters V and VI;

(v) for Barkakana and Haidernagar, utilisation of the nearest coal has been assumed for ammonia synthesis.

It will be seen that the production costs are the lowest for Rourkela, Bhadravati and Mirzapur due to the assumed availability of cheap hydrogen at the first location and of cheap hydro-electric power at the latter two locations, other factors being more or less equal for all locations. The cost of production is the lowest at Rourkela; on the other hand, the present indications are (see para 23, Chapter III) that even the hydrogen fraction of coke oven gas may not be available there at all. The next best location is Mirzapur

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*This is the current rate for Jogfalls power. The future rate may be lower still—see para 3 (ii) Chapter IV.

† See in this connection para 3(ix) Chapter IV.

where the cost of production now estimated is likely to go down still further when communication facilities‡ are established for the economic exploitation of Singhrauli coal and it is possible to utilise local coal in place of coal brought from Bihar coal fields. When this happens Mirzapur§ will probably be the most ideal location for a nitro-limestone factory in North India, failing Rourkela. Bhadravati costs would always remain slightly higher than production costs at Mirzapur because the adoption of the electrolytic process for ammonia synthesis is unavoidable at Bhadravati. Nevertheless, after Rourkela and Mirzapur, Bhadravati offers the greatest advantages for economic production of nitro-limestone: and in any case it is unquestionably the most suitable location for a nitro-limestone factory south of the Vindhyas. We suggest accordingly that should it in future be decided to establish a nitro-limestone factory, consideration should be given, failing Rourkela, to the two suggested locations at Mirzapur in Uttar Pradesh and Bhadravati in Mysore; and if a selection has to be made as between these two locations, the main governing factor should be their relative proximity to the anticipated consumer points.

5. In Chapter II we have advocated similarly further investigations with a view to establish the suitability of the following other types of chemical fertilizers, *viz.*,

(i) ammonium phosphate;

(ii) nitro-phosphate;

(iii) ammoniated super-phosphate; and

(iv) ammonium chloride (in association with manufacture of Soda Ash).

For the manufacture of any phosphatic fertiliser the most convenient location would naturally be a place reasonably near a sea port, since whatever may be the location of the factory, it will have to use phosphatic rocks imported from abroad. The chief raw materials for ammonium chloride being coke and common salt, a factory designed to manufacture this product should be conveniently located near the sources of these materials. Taking these facts into consideration, we suggest that the potentialities of the following locations might be usefully investigated for establishing the manufacture of any of the products mentioned above:

(1) Bombay (for only phosphatic fertilisers);

(2) Neyveli;

(3) Vijayawada;

(4) Kothagudiam; and

(5) Durgapur.

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‡ The entire area is totally undeveloped and the first requirement is that it should be opened up and made easily accessible. As an immediate measure we suggest that the Chunar-Robertsgunj-Churk railway line should be extended across the Son to the dam site at Pipri; and as soon as possible thereafter, further extended to allow access to the Singhrauli coal fields. Ultimately the branch line should be connected with Anuppur or Chirmiri on the Eastern Railway.

§ All things considered, the best location for the factory would probably be on the left bank of the Son, between Robertsgunj and Pipri, nearabout the projected road bridge on the river.

(2) INCREASE IN PRODUCTION TARGET UP TO THE FULL ESTIMATED REQUIREMENTS OF MINISTRY OF AGRICULTURE

6. In connection with the establishment of facilities for the manufacture of nitro-limestone and phosphatic fertilisers we would advert, once again, to the suggestion we have made* for increasing the nitrogen production target fixed in our terms of reference. In making our recommendations in Chapter V we have visualised the possibility of Government's agreeing to increase the production target by about 20,000 tons or at the most 50,000 tons of nitrogen per year. Should Government take a decision to increase the production target upto the full requirement estimated by the Agriculture Ministry, that is by 80,000 tons, we would suggest that the issue should be considered simultaneously with the possibility of establishing the production of a cheaper type of nitrogenous fertiliser other than ammonium sulphate or double salt. We have recently been given to understand informally that the Ministry of Agriculture are now inclined to accept nitro-limestone as a suitable fertiliser in limited quantities for acid soils in the south and in the east provided the hygroscopicity of the end-product can by special treatment be sufficiently reduced to enable it to stand the climatic conditions of these regions. Without making elaborate experimental studies, for which we have neither the time nor the necessary facilities, it is not possible for us to pronounce any opinion as to the possibility of giving such special treatment to nitro-limestone as would ensure its satisfactory keeping† quality. All that we are in a position to suggest at the moment is that should a type of specially treated limestone be finally accepted as a suitable fertiliser for the humid areas in the south and the east and should it be decided at the same time to increase the production target up to the full requirement estimated by the Agriculture Ministry, consideration should be given to the production of the extra 80,000 tons of nitrogen at a conveniently located plant partly in the form of urea by the "once through" process and partly as nitro-limestone.

(3) ESTABLISHMENT OF CERTAIN CENTRAL INSTITUTIONS

7. In dealing with the question of implementation of our recommendations in Chapter VII we have advocated the establishment of a Central Fertiliser Board with a Standing Technical Committee functioning under its control for the duration of the construction of the new plants. This Committee, we have suggested, should, as an initial step, equip itself with a large drawing and designing office where the new plants may be designed in collaboration with foreign experts and consultants. We contemplate that the drawing and designing office should be a permanent central institution; after the designing of the new plants is completed and the specifications for different sections are drawn up, the Central Drawing and Designing office will have of course to be reduced in size but a nucleus staff should be retained so that the experience gained during the construction of the new plants may not be lost and it may not be necessary in future to approach foreign firms for additions and alterations, large or small,

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* See para 15 of Chapter II and section 4 of Chapter V.

†We have however requested the Sindri Technological Organisation to set in train the necessary experimental investigations of which, we hope, the results will be available within 6 to 8 weeks.

in any of the State-owned chemical plants. We suggest for consideration that the Central Drawing and Designing Office may be most conveniently located at Sindri where some facilities are already available and the organisation will not have to be built up from scratch.

8. A worth-while objective which, we have ventured to hope, will be realised in consequence of the pooling and centralisation of technical resources which we have recommended is the establishment of facilities, on the completion of the current expansion programme, for the evolution and perfection of new techniques and processes in the field of practical chemical engineering*. As an important step towards the fulfilment of this objective we suggest the establishment at an early date of a Central Technological Research and Development Bureau for which, again, the most convenient location would probably be Sindri. We refer in this connection to the observations made by the Indian Fertiliser Mission in para 47 of its report where the Mission has described in some detail the research and development facilities that have been established in foreign concerns comparable to Sindri even as "a good business and dividend-earning proposition". With the multiplication of the number of production units and the establishment of a central controlling and guiding authority, there would be a rare opportunity for building up on firm foundations high-level facilities for technological investigations and research studies. With the existing small technological organisation at Sindri as a nucleus a much larger institution should, we suggest, be organised simultaneously with the progress of construction of the new factories. While each new factory should have a branch research and development organisation, conducting its investigations at somewhat lower levels, it is essential that adequate facilities should be established for high-level experimental studies and investigations at a well-equipped and well-staffed central institution where problems of relatively greater complexity can be tackled and independent investigations can be taken in hand in such matters as *e.g.*, utilisation of indigenous resources to the best advantage, improvement of processes with a view to reduce manufacturing costs, evolution of new techniques, erection and operation of pilot plants etc. etc.

9. Side by side with the development of research facilities, we recommend that a start should be made with the establishment of fabrication facilities in the country—another line of development of which the need was stressed by the Indian Fertilizer Mission in para 47 of its report. In the past it has been necessary to resort to foreign manufacturers for the supply of not only standard equipment but even minor spare parts. At Sindri for example, it has been necessary so far to depend on foreign firms for practically all requirements of replacements and spares including even minor pieces of equipment. The time has come, we suggest, when steps should be taken to eliminate or at least largely reduce this dependence on foreign countries. We were impressed by the fabrication facilities that have been established in connection with the Bhakra dam construction at Nangal; and we were equally impressed by the manner in which the Sahu-Jain group of factories at Dalmianagar are learning to help themselves. Fabrication potential at Dalmianagar workshops is already

* See in this connection para 7 of Chapter VII.

very considerable and a scheme for its large-scale expansion is now being put through under the supervision of a newly recruited German expert. We recommend that a central fabrication workshop for all State-owned chemical factories should be established at Nangal, the existing workshops there being taken as a nucleus for the purpose Although this will involve initially a fairly large capital investment, we are convinced that the investment would be fully worthwhile and before long, earn handsome dividends not only in the shape of increased confidence and better morale but in terms of money as well. Heavy chemical industries generally and, in particular, the State-owned fertiliser production units, present and future, will save a great deal of money ultimately if the organisation of a central fabrication workshop is undertaken with determination and carried out efficiently under expert guidance. The Indian workman has already given ample evidence of his inventive ability and technical aptitude in applied mechanics and, given some support and encouragement and energetic pursuit of the task, it should not be long before it becomes possible to produce in the country even complicated pieces of machinery requiring practical experience and a high degree of skill. We are naturally unable at this stage to indicate precisely how the fabrication workshops at Nangal should be reorganised and orientated for the fulfilment of the objective we have in view. This, however, is one of the many matters (including organisation of research facilities) which the Standing Technical Committee will have to investigate and advise on.

(4) STANDARDISATION OF PLANT AND EQUIPMENT

10. Another matter which, we suggest, should claim the attention of the Standing Technical Committee is the need for standardising the more important plant and equipment for production of nitrogenous fertilisers. It is obviously much better that such equipment as ammonia converters or urea reactors should follow a standard pattern in order that, firstly, their design and construction in this country may be facilitated; secondly, their spare parts may be interchangeable; and thirdly, technical personnel can be transferred from factory to factory without having to be given a special course of training on the occasion of each transfer. We recommend that the Standing Technical Committee should be specially invited to study the problem in all its aspects and make suitable recommendations as to

(i) the particular categories of equipment which can be economically and usefully standardised; and

(ii) the sizes and specifications which should be laid down for the selected categories.

(5) AVAILABILITY OF POWER FOR THE NANGAL PROJECT

11. In our interim report on the Nangal Project we noted that "our discussions with the officials of the Punjab Government connected with the Bhakra-Nangal Project have established that there would be no difficulty in obtaining the required supply of electrical energy". We recommended accordingly that "arrangements should be made at once for the installation of the required power generating capacity at Bhakra-Nangal so as to make available to the new fertiliser-*cum*-heavy water factory a firm all-the-year round power supply of round about 160,000 K.W. at a load factor of 90 per cent". We hoped that in indicating an average power requirement of 160,000

K.W. at a load factor of 90 per cent, we had made it clear that the *peak* requirement of power would be of the order of nearly 178,000 K.W. In our previous discussions with the Bhakra-Nangal authorities it was definitely confirmed that firm power of this order (or even more, if required) can be made available provided the power units established at Ganguwal and Kotla are supplemented by the installation of 4 generators each of 90,000 K.W. capacity at Bhakra. We understand, however, that doubts have lately been felt about the possibility of power generation of this order at Bhakra. At a conference which we had with the Chief Electrical Engineer of the Punjab Government and the head of the Bhakra Dam Design Directorate on the 30th April it was clarified that *on the basis of existing plans for release of water for irrigation purposes,* it would not in any case, be possible to count on a larger peak supply than 160,000 K.W.; and even then the supply would fall short of the reduced peak in exceptional years. We were told that, on the basis of an analysis of the data for the past 30 years, it has been concluded that the generation capacity would have fallen short of 160,000 K.W. in 5 out of 30 years during limited periods. In 4 out of these 5 years, the period of shortage would have been one month and in the fifth year it would have been more than a month but less than two months. On the other hand, if an average is taken of the entire period of 30 years, the generation capacity of Bhakra would be 240,000 K.W. throughout every year.

12. This is a new situation which we have carefully considered and discussed in some detail with the officials connected with Bhakra-Nangal project. Wide fluctuations in hydro-electric power generation are only natural, particularly if, as in the case of Bhakra Nangal, hydro-electric generation is only a part of a multi-purpose project and is not buttressed by seasonal generation of thermal power. Assuming that the pattern and incidence of rainfall and, therefore, the Bhakra lake reservoir capacity from time to time, would be more or less the same in future as they have been in the past, the net situation is that in something like six months out of a total period of 360 months, the Bhakra power generation capacity would be less than the quantum of power which a 70,000 tons/year nitrogen plant at Nangal would require. While we do not consider the situation* to be alarming in any sense, it is clear that it should be reckoned with in advance. The possible solutions appear to be:

(1) The present plans for release of water for irrigation purposes should be revised so as to increase the potentialities of firm all-the-year-round power generation. We were given to understand that this issue is already under consideration and that it is almost certain that the present programme for releasing water from Bhakra would be modified having regard to the additional waters that would be available for irrigation purposes on the completion of the Ravi link now under construction. In case the modifications which the Ravi link appear *prima facie* to justify are made, there would, we have been assured, be no shortage of power below 160,000 K.W. for any period in any year.

* The situation can, within limits, be met by arranging for the necessary plant overhauls/repairs/catalyst changes to be made during periods of anticipated short supply of power.

It is possible to design the Nangal fertiliser *cum* heavy water plant with a view to achieve 98 per cent stream efficiency (instead of the normal 90 per cent) in which case the production capacity of 70,000 tons of nitrogen and 7½ tons of heavy water per year would be attainable even counting on a *peak* supply of not more than 160,000 K.W. Although to design the factory on this basis would involve the installation of appreciably more spare equipment than what is considered normal, it would at the same time be possible, in view of the higher stream factor, to reduce the maximum designed capacity and yet achieve the same production; consequently there would be little overall increase in capital investment.

(2) In case it is ultimately concluded that it would not be expedient to alter the approved programme of releasing water from Bhakra reservoir in the manner indicated in (1) above, the peak power supply would be short of the requirements of a 70,000 tons nitrogen/year factory for short periods during some years even if the factory is designed for a stream factor of 98 per cent. In that event and assuming that the capacity of the fertiliser factory we have recommended in our interim report will not be altered in any way, the factory would undoubtedly suffer some loss in production in years of short supply of power. This loss can be made good in one of the following ways:

(a) the actual loss suffered due to heavier incidence of capital charges and labour costs on account of reduced production may be made good by an appropriate reduction in the cost of power supplied throughout the year of short supply;

(b) secondary power may be made available at a cheaper rate; for this purpose power from two out of the four Bhakra units, that is 106,000 K.W., may be regarded as firm power and priced at 2.6 pies per unit, the power from the third unit being then regarded as secondary and priced at a reduced rate. The extent of reduction will have to be negotiated but may well be 12½ per cent in which case the price of secondary power would be 2.27 pies per unit;

(c) an overall reduction may be allowed in the currently agreed rate for supply of power to the fertiliser *cum* heavy water factory to an appropriate extent so as to cover the anticipated loss due to short production for certain periods in certain years.

(3) A third solution would be to reduce the capacity of the nitrogen *cum* heavy water plant from 70,000 tons to say 60,000 tons of nitrogen per year with a corresponding reduction in the yield of heavy water. The reduced yield of heavy water would still be well above the Atomic Energy Department's requirement of 5 tons per year. The average power requirement would, in that case, be 135,000 K.W. and the peak supply required 150,000 K.W. While this solution would leave a certain quantity of spare power with the Bhakra-Nangal authorities for supply to the public and other industrial concerns and would at the same time render it possible for the fertilizer *cum* heavy water factory to be designed on the usual stream factor basis, it would, on the other hand, involve some rise in the production costs estimated by us. The increase in production costs would, we have roughly calculated, be of the order of Rs. 30 per ton of nitrogen. The

increased cost of production would, however, still favourably compare with the cost of production of nitrogen at Sindri in the form of ammonium sulphate.

13. The whole issue is somewhat complicated and before any definite recommendation can be made or any sensible conclusions can be reached it requires further discussion with the Bhakra Nangal authorities, particularly in the context of the possiblity of modifying the present plans for releasing water from the Bhakra lake for irrigation purposes. We could at this stage merely indicate certain possible solutions but it is obvious that before any decision can be reached, our suggestions will have to be investigated in detail. We note that should it be ultimately decided to reduce the recommended nitrogen capacity of the Nangal plant to a lower figure, a higher margin than 100,000 tons of nitrogen a year which we have assumed throughout our discussions, would be available for the other fertiliser production units.

(6) REDUCTION OF RAILWAY FREIGHT ON GYPSUM

14. In the course of our investigations we have been impressed by the fact that one important reason why the manufacture of ammonium sulphate/double salt on the basis of utilisation of indigenous gypsum is relatively expensive is the high freight charges that are at present levied for transportation of gypsum by railway. In this respect freight on gypsum compares markedly unfavourably with that on coal. We suggest for consideration that at least to the extent that gypsum is utilised for manufacture of fertilisers it should be regarded as a commodity as essential to the life of the community as coal and that the freight rates on both these commodities should, for this reason, be completely equalised. We hope that this proposition for which, we think, there is every justification, will receive the favourable consideration of the concerned authorities. We understand that railway freight on Rajasthan gypsum intended for utilisation in the Sindri plant has, as a special case, been reduced by 20 per cent. We suggest that reduction in freight on gypsum to at least this extent should be allowed for every fertiliser factory that may be installed under the current expansion programme.

P. M. NAYAK
Secretary.

B. C. MUKHARJI
Chairman

A. NAGARAJA RAO
Member

M. D. PAREKH
Member

K. C. SHARMA
Member

Dated New Delhi, the 4th June 1955

ANNEXURES

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ANNEXURE I

GAZETTE EXTRAORDINARY

GOVERNMENT OF INDIA

MINISTRY OF PRODUCTION

New Delhi, the 29th October 1954

RESOLUTION

*No. Fy.*I-17(1)/54—In view of the importance of nitrogenous fertilizers for augmenting food production, the Government of India have been considering the need for expanding the indigenous capacity for the production of these fertilizers. The current capacity is inadequate to meet the internal demand and it is expected that this demand will rise steadily during the coming years. The Government have come to the conclusion that the creation of further capacity in the country is essential if large scale imports are to be avoided. It has been estimated that fresh capacity for producing 2.5 lakhs of tons per annum (in terms of nitrogen) will need to be set up by the year 1961 and it is proposed that as a first step immediate action should be taken for planning and creating additional capacity for 1.7 lakh tons of nitrogen per annum. It is estimated that there will be enough demand to absorb this additional supply. The Government of India have accordingly decided to constitute a Committee to consider and make recommendations on the various questions involved in the creation of fresh capacity.

2. The Committee will consist of the following:—

(1) Shri B. C. Mukharji, I.C.S. ...	Chairman.
(2) Dr. A. Nagaraja Rao, Chief Industrial Adviser to Government ...	Members.
(3) Dr. M. D. Parekh, Chairman of the Development Council for Fertilizers and Heavy Chemicals	Members.
(4) Shri K. C. Sharma, Sindri Fertilizers and Chemicals Ltd.	Members.
(5) Shri P. M. Nayak, I.C.S., Deputy Secretary, Ministry of Production ...	Secretary.

3. The following will constitute the terms of reference to the Committee;

(1) To suggest possible locations for the new fertilizer factories for the production of ammonium sulphate, ammonium sulphate-nitrate and urea having regard to all relevant considerations including adequacy of transport and the proximity of consumer points:

(2) To indicate the quantities of one or more of these fertilizers that could be produced at each location on an economic basis, the processes to be adopted and the probable cost of production;

(3) To estimate roughly the capital and working cost of the plants recommended at the different locations;

(4) To make recommendations regarding the requirements and the provision of technical personnel for staffing the new plants; and

(5) To suggest the best method of further processing the Committee's recommendations.

4. The Committee will be designated "The Fertilizer Production Committee" and will have its headquarters at New Delhi. It will assemble as early as possible and will submit its reporte to Government within a period of 3 months.

S. S. KHERA
Secretary to the Government of India

Order: Ordered that a copy of the Resolution be communicated to all concerned.

Ordered also that the Resolution be published in the Gazette of India for general information.

S. S. KHERA
Secretary to the Government of India

New Delhi, the 1st *November* 1954

No. Fy.I-17(1)/54—Copy forwarded to all State Governments (Parts A, B, C and D), all Ministries of the Government of India, Cabinet Secretariat, Prime Minister's Secretariat, Secretary to the President, the Indian Trade Commissioners, all Indian Embassies, all the High Commissioners for India and also to Department of Atomic Energy, Apollo Pier Road, Bombay 1.

D. S. BENEGAL
Under Secretary to the Government of India

ANNEXURE II

STATEMENT OF PLACES VISITED BY THE FERTILIZER PRODUCTION COMMITTEE

Serial No.	Place visited	Date of visit
1	Nangal	12th and 13th January 1955.
2	Nagpur	24th and 25th January 1955.
3	Hyderabad (Deccan)	26th and 27th January 1955.
4	Kothegudium	28th January 1955.
5	Ramagundam	29th January 1955.
6	Kurnool	30th and 31st January 1955.
7	Bangalore	1st and 2nd February 1955.
8	Madras	3rd February 1955.
9	Ariyalur	4th February 1955.
10	Trichinopoly	4th February 1955.
11	Neyveli	5th February 1955.
12	Cuddalore & Pondicherry ..	5th February 1955.
13	Bezwada	7th February 1955.
14	Masulipatam	7th February 1955.
15	Bhubaneswar	9th February 1955.
16	Cuttack	10th February 1955.
17	Calcutta and Durgapur	12th to 14th February 1955.
18	Bikaner	23rd February 1955.
19	Jamsar and Palana	24th February 1955.
20	Hanumangarh (Rajasthan) ..	25th February 1955.
21	Bombay and Poona	1st March and 3rd March 1955.
22	Halmak (site for Koyna dam) ..	2nd March 1955.
23	Karad	2nd March 1955.
24	Rajkot	5th March 1955
25	Jamnagar	6th March 1955.
26	Sikka	6th March 1955.
27	Dwarka	6th March 1955.
28	Bhatia, Ran & Virpur	7th March 1955.
29	Bharatpur	15th March 1955.
30	Dalmianagar & Amjor	26th and 27th March 1955.
31	Hoshangabad—Bagra—Belwara (Itarsi). ..	30th May 1955.

ANNEXURE III

FERTILIZER PRODUCTION COMMITTEE

Interim report on Bhakra-Nangal Project

One of the terms of reference to the Fertilizer Production Committee is "to suggest possible locations for the new fertilizer factories for the production of ammonium sulphate, ammonium sulphate-nitrate and urea having regard to all relevant considerations including adequacy of transport and proximity of consumer points:" In communicating this term Government have, however, issued a directive that one of the new fertilizer units will have to be located in the Bhakra-Nangal area and must be set up in close association with the project for the manufacture of heavy water. The Committee's attention has, in this connection, been drawn to the availability of cheap electric power on the required scale at Bhakra-Nangal, offering good prospects of economical production of nitrogenous fertilizers.

2. Government's decision to locate a fertilizer unit at Nangal in association with manufacture of heavy water limits to some extent, at least by implication, our choice of both process and product. Since the decision is to produce the basic fertiliser material, ammonia, in conjunction with heavy water, the process to be adopted has to be based on electrolysis of water which will yield, along with heavy water, hydrogen, the other component of ammonia being collected from the atmosphere by liquefaction and fractionation of air. The selection of this process, again, rules out, for economic reasons and, therefore, for all practical purposes, any of the three nitrogenous fertilisers specifically mentioned in our terms of reference. Carbon dioxide which is a basic raw material required for the production of either urea or ammonium sulphate (by the gypsum process) would not be available as a co-product if ammonia is produced by the process of electrolysis of water and liquefaction of air. If carbon dioxide has to be specially arranged for by, for example, burning limestone or coal or coke imported from Bihar coal fields, the end-product would naturally be expensive and the cost per unit of nitrogen unreasonably high. And an almost equally expensive end-product would be the consequence (due to Nangal's great distance from the nearest sea port), should arrangements be made to manufacture ammonium sulphate from imported sulphur or pyrites. The only nitrogenous fertiliser that can, in the circumstances, be economically produced in association with heavy water is ammonium nitrate for which no other raw material would be needed except ammonia itself.

3. Although our terms of reference, strictly speaking, preclude us from considering the production of any but the three types of nitrogenous fertilisers mentioned there, namely, ammonium sulphate, ammonium sulphate-nitrate and urea, certain papers which we have received in connection with Government's directive about the location of one of the new fertiliser units at Nangal indicate that it would be in order for us to recommend, so far as this particular plant is concerned, the production of a suitable type of ammonium nitrate fertiliser. Fortunately our conclusion about the particular product which alone, we think, can be economically manufactured at Nangal, fits in with the views of the Ministry of Agriculture also. According to the data and materials we have received from that Ministry, it appears that the Ministry's first *preference is a

* We would, in agreement with the views of the Ministry of Agriculture rule out production of anhydrous ammonia at Nangal as an end-product despite the fact that certain advanced countries have recently started to favour direct application of ammonia as a cheap source of the primary plant nutrient *i.e.* nitrogen. We are convinced that neither Indian cultivators generally nor our current agricultural practices are advanced enough to justify introduction of liquid ammonia as a usable fertiliser at present.

suitable type of ammonium nitrate fertiliser (their second preference being urea) for the area covered by Jammu and Kashmir, Himachal Pradesh, the Punjab, Pepsu, Delhi, U. P. and the North-Western portion of Rajasthan commanded by the Bhakra-Nangal irrigation system. We are in agreement with the view of the Ministry of Agriculture that despite American practice to the contrary, the ammonium nitrate fertiliser to be produced at Nangal should be diluted with an inert material so as to eliminate explosion hazards and ensure reasonably good keeping quality of the final product. In this matter we should we think, eschew the American example which is to use as fertiliser pure ammonium nitrate in a prilled or granulated form in disregard of the fact that the product is a potential explosive, and follow, instead, the universal European practice of manufacturing fertiliser grade ammonium nitrate with a diluent so as to bring down its nitrogen content. In regard to the diluent we have been advised by the Agriculture Ministry that it should be an inert material other than limestone having regard to the calcareous nature of the soils of the Punjab and Western regions. We have not yet been able to finally settle the particular inert material or even the kind of material that would be most suitable as a diluent of ammonium nitrate in this country; nor the extent to which ammonium nitrate must be diluted in order to eliminate its explosion hazards. The end product need not necessarily have as low a nitrogen content as 20.5 per cent, which represents the usual dilution in commercial products manufactured and used abroad. There would obviously be great advantage in keeping the nitrogen content in the end-product as high as possible consistently, of course, with freedom from explosion risks; a product with comparatively high nitrogen content would not only be cheaper on a nitrogen basis but would also achieve considerable saving in transportation costs. While, however, these unsolved problems have still to be tackled, their solution would, we are confident, ultimately present no difficulty. Before making any firm recommendations with respect to them, we are awaiting the results of certain experimental studies, in particular, of certain technological investigations that we have already set in train at Sindri.

4. On a consideration of such material factors as soils, crops and climatic conditions, the Ministry of Agriculture have recommended for the northern zone, comprising the States and areas mentioned in the last paragraph, a total production of 90,800 tons of nitrogen in the form of ammonium nitrate suitably diluted with an inert material so as to reduce its explosion hazards and improve its keeping quality. They further recommend production of 12,800 tons of nitrogen in the same form for the western zone comprising the rest of Rajasthan, Ajmer, Madhya Bharat, Vindhya Pradesh, Bhopal, Saurashtra, Kutch, Bombay and Hyderabad. The total quantity of ammonium nitrate fertiliser which the Ministry of Agriculture, in other words, would desire to have for the two areas mentioned above is, in terms of nitrogen, about 103,600 tons which should, for our present purposes, be reduced by about a third since we have been asked to arrange for a total new production of roughly two-thirds of what would be according to the Agriculture Ministry's computation, the total nitrogen demand of the country by the year 1961 *less* existing production. If, thus, we are to be guided by the Agriculture Ministry's views and recommendations, we should plan the establishment of facilities for the production of roughly 70,000 tons of nitrogen in the form of a suitable ammonium nitrate fertiliser at one or more places which can serve, from the consumer's angle, as convenient supplying centres for the northern and western zones mentioned above.

5. The conclusion just noted above sets for us the *maximum* nitrogen production capacity of the proposed Nangal plant, for even if the entire requirement of ammonium nitrate fertiliser were to be met by a single production unit, the plant would have no higher production capacity than 70,000 tons of nitrogen a year. The *minimum* production capacity of the

Nangal unit is fixed indirectly by the directive issued by Government in the light of which a part at least of the total production of ammonium nitrate fertiliser has to be established at Nangal. The decision to fix nitrogen in conjunction with heavy water implies that the size of the unit must be large enough to meet fully the entire heavy water requirements of the Atomic Energy Commission. In personal discussion with the head of the Atomic Energy Department it has been clarified that for several years to come the department's steady annual requirement of heavy water is likely to be of the order of 5 tons; but we have been assured that there would be no difficulty on the part of the Atomic Energy Commission in arranging for the offtake of any quantity of heavy water that can be produced at Nangal. The indication we have thus received of the Atomic Energy Commission's requirements of heavy water leads to the conclusion that the *minimum* nitrogen fixation capacity of the combined project must be at least commensurate with the production of 5 tons of heavy water a year which means a yearly nitrogen production of about 50,000 tons.

6. Within the maximum and minimum limits mentioned above, the correct size of the plant and its production capacity is a matter for determination in the light of (a) requirements of the area for which Nangal can be regarded as a suitable producing and supplying centre; and (b) overall economics of production.

As regards the first factor (a), we have been given to understand in discussion with the officials of the Ministry of Agriculture that Nangal would, in their view, be a convenient centre for the production of ammonium nitrate fertiliser for the whole of the Northern Zone where the major portion of the new production is likely to be consumed; and they would prefer, unless overwhelming economic reasons dictate a contrary course, that the relatively small requirement of the Western Zone should also be met by the same production units.

With regard to the other factor (b), economics of production, we have considered the matter from two angles, namely, (i) relative economics of production of ammonium nitrate at Nangal and Sindri; and (ii) relative economics of production of nitrogen in the form of ammonium nitrate or nitro-limestone at Nangal and in some other form somewhere else.

We have accordingly attempted to work out costs of manufacture of ammonia and ammonium nitrate at Nangal:

(i) in a unit of minimum size, *i.e.*, with a production capacity of 50,000 tons of nitrogen per year; and

(ii) in a larger 70,000 tons nitrogen/year unit, so as to judge how they compare with

(a) each other;

(b) cost of production of identical products manufactured according to a different process at a place favourably situated from the point of view of availability of the main raw material required for that process;

and (c) cost of production, on a nitrogen basis, of ammonium sulphate produced at Sindri.

We have also tentatively worked out costs of manufacture of nitro-limestone at Nangal in the larger capacity plant with a view to judge how they would compare, on a nitrogen basis, with the cost of production of ammonium sulphate at Sindri. Since, in accordance with the Agriculture Ministry's advice, the final product at Nangal will probably be, not nitro-chalk or nitro-limestone with the usual 20.5 per cent. nitrogen content, but ammonium nitrate more moderately diluted with some inert

material other than limestone, it would be reasonable to *assume that the manufacturing costs of the special "Nangal salt" will be less than those of nitro-limestone.

We have not considered it necessary to compare the estimated production costs of ammonium nitrate and nitro-limestone at Nangal with the cost of production of urea at any particular centre because, in the first place, urea would be a cheaper product to make anywhere *where the necessary raw materials are available on the spot* and, secondly, for reasons already explained, urea cannot in any case be produced economically in conjunction with heavy water.

7. The results of this comparative study are set out in the Appendices to this report. The cost calculations in the Appendices are prefaced by an explanation sheet where certain assumptions relating to basic data and the correct implications of the results arrived at have been elucidated. It will suffice to note here that:

(a) the cost of production of ammonia and ammonium nitrate in the smaller plant at Nangal would be Rs. 22 per ton and Rs. 19 per ton more, respectively, than the corresponding cost of production in the larger capacity plant. Actually the difference will be more marked if, as has been indicated to us, electrical energy would be charged for at a higher rate for the level of consumption required for the lower capacity plant. Even if the cost of energy goes up by only 10 per cent for the lower offtake, the difference in production costs would increase to Rs. 41 per ton of ammonia and Rs. 28 per ton of ammonium nitrate;

(b) the production cost of ammonia at Nangal would be Rs. 10 per ton higher in the larger plant and Rs. 32 per ton higher in the smaller plant than the production cost of ammonia at Sindri by the semi-water gas process. This is because (i) the capital cost of an ammonia plant based on electrolysis/liquefaction process is considerably larger than that of a plant using coal or coke gas; and (ii) this advantage is not offset at Nangal by a sufficiently low price of electrical energy which is the main raw material consumed in bulk in the process on which a combined heavy water *cum* nitrogen plant has to be operated;

(c) despite the higher cost of ammonia at Nangal ammonium nitrate would be cheaper to make there in the high capacity plant (but not in the smaller plant) than at Sindri. This is due to the fact that the main utilities, power and water, would be available at Nangal at a very much lower cost;

(d) ammonium nitrate produced at Nangal and also nitro-limestone in the high capacity plant, would be a cheaper product on a nitrogen basis than ammonium sulphate produced at Sindri; and

(e) from certain tentative †estimates which we have either ourselves prepared or received from other sources we conclude that on a nitrogen basis ammonium nitrate or nitro-limestone produced at Nangal in the larger capacity plant would be a cheaper product than ammonium sulphate produced at Neyveli in South India or at a convenient location like Agra or Bharatpur in the United Provinces.

8. Considering the matter, therefore, either from the point of view of (a) fertiliser requirements of the area which Nangal may conveniently serve as a producing and supplying base; or (b) overall economics of

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* cf. the reasons given in para (ii) of the prefatory note introducing the appendices.

† These estimates are not included in the Appendices.

production, we reach the conclusion that the optimum capacity of the nitrogen production unit at Nangal should be of the order of 70,000 tons of nitrogen per year. With a plant of this capacity Nangal should, we expect, be able to offer its fertiliser for sale at a competitive price, comparing very favourably, on a nitrogen basis, with the price of ammonium sulphate or sulphate-nitrate produced anywhere in the country or imported from abroad. We note that the Sindri plant (without taking into account the contemplated expansion) has, in terms of nitrogen, the same production capacity as what we are recommending for the Nangal plant.

9. An examination of the Appendices will indicate that subject to the reservations we have explained in the prefatory note the capital and working costs of the Nangal plant are likely to be of the same order as what we have estimated for a nitro-limestone plant with a capacity of 70,000 tons of nitrogen per year *i.e.* about Rs. 19½ crores or (say) Rs. 20 crores and Rs. 800 per ton of nitrogen content respectively. We wish, however, to make it clear that these estimates are at this stage of an extremely tentative nature. They are based partly on the data and materials given in Dr. Brun's report on "the feasibility of heavy water production in India" and partly on certain data in our possession which we have collected from a number of Chemical Engineering Firms of international reputation. Firmer figures of likely capital investments will be furnished in our final report; the figures on the basis of which we have made our cost calculations are, however, reliable enough to justify the conclusions we have set out in this report.

10. Apart from capital investment, the only main factor which will govern production costs at Nangal is cost of electrical energy. A factor of major importance that must be taken into account in this connection is that the process of manufacture of ammonia, to which our choice must be limited at Nangal for the reasons explained above, requires very heavy consumption of electrical energy and is a process which is adopted only where electricity is both abundantly available and is also extremely cheap or where coke or coal is unobtainable or can be had only at a unduly high cost. Our discussions with the officials of the Punjab Government connected with the Bhakra-Nangal project have established that there would be no difficulty in obtaining the required supply of electric energy; on the other hand, we are not entirely satisfied that the energy would be available at a sufficiently low cost. In our first discussion with the Chief Electrical Engineer of the Punjab Government on the 16th November we were told that according to the present calculations of the Bhakra-Nangal authorities, "based on the installation of 4 units at Nangal of 24,000 K.W. each and *one unit* at Bhakra of 53,000/90,000 K.W. (giving an ultimate load capacity of 1,76,000 K.W. on the inter-connected system), the generation cost at an overall annual load factor of 80 per cent would be about 2.6 pies per unit." We had hoped that were we to propose a large enough plant to justify the installation of more than one generating unit at Bhakra, the generation cost would come down to an appreciable extent. Our expectations in this regard have, however, been belied in the subsequent discussions we have had with the officers of the Bhakra Dam Design Directorate and the Electrical Engineering Department of the Punjab Government. In the last discussion we had with the Chief Electrical Engineer of the Punjab Government, he mentioned that it has now been decided to charge against "Power" certain capital costs which it was originally proposed to charge against "Irrigation" with the consequence that even though 3 or 4 generators are installed straightaway at Bhakra, the cost of power would still be of the order of 2.6 pies per unit. The cost of power plays such a prominent part in the determination of the cost of the end-product, if ammonia is manufactured by the process of electrolysis/liquefaction, that we have been anxious to find out the level

of consumption of electricity at which its cost would be the lowest. The upto-date indications which we have received, however, go to show that if the firm power demand is of the order of 110/112,000 K.W., which is enough for the production of about 50,000 tons of nitrogen along with a little over 5 tons of heavy water per year, the cost per unit of power might be somewhat higher than 2.6 pies per unit; and that, on the other hand, if the firm power demand is of the order of 157,000 K.W., which would be required for the production of 70,000 tons of nitrogen along with between 7 and 8 tons of heavy water per year, the cost *would not exceed* 2.6 pies per unit and may, in fact, be somewhat lower, provided a market can be found for the secondary power. In these circumstances, we have considered it reasonable to base our calculations of production costs on the assumption that power per unit will be charged for at 2.6 pies whether the offtake is of the order of 157,000 K.W. or of the order of 112,000 K.W.

11. Even though economical production of ammonium nitrate fertiliser would be possible at Nangal on the basis of an energy cost of 2.6 pies per unit, we would suggest that the possibility of further reducing the cost of hydro-electric energy from the Bhakra-Nangal system should be fully explored. We gather from Dr. Brun's report that in Norway "the price of electric power used in the electro-chemical and electro-metallurgical industries may be placed on the average at about 0.08 annas per unit and several well-established Norwegian industries possessing their own power stations are operating with power at a cost of less than half of this figure. Assuming proper utilisation of secondary power, we see no reason why the cost of firm power for the fertilizer *cum* heavy water project should not be appreciably lower than what we had to accept as a basis for our present calculations. Secondary power should be available at practically no cost, but unfortunately cannot be utilised in a nitrogen plant because that would mean seasonal operation of the factory which is completely out of the question in a heavy chemical plant involving large capital investments.

12. In view of the directive of Government that one of the new fertiliser units must be located in the Bhakra-Nangal area, it has been unnecessary for us to make any meticulous comparison (and we are, in any case, not yet in a position to do so) of the relative economics of production of nitrogenous fertilisers at Bhakra-Nangal as compared with other locations having equal or better advantages in the matter of proximity of consumer points, nearness to sources of raw materials, etc. The results of the rather rough and ready comparisons we have made (cf. paragraph 7 *ante*) are however definitely encouraging and have led us to conclude, at least provisionally, that quite independently of the directive of Government the establishment of an ammonium nitrate fertiliser factory at Nangal would be an economical proposition and also a feasible plan from the point of view of (i) the Agriculture Ministry's requirement (ii) proximity of consumer points, and (iii) transportation and communication facilities.

13. We have, besides, been impressed with certain undoubted advantages which a fertiliser factory at Nangal would have, apart from availability of abundant electricity, perennial supply of any quantity of water from the Nangal lake and the fact that the location is eminently suitable for the production of heavy water. To briefly summarise these advantages, they are—

(1) Nangal is a township of 12,000 inhabitants (complete with primary, middle and high schools, markets, clubs and recreation centres, and a 54-bedded hospital) 9/10th of which will be vacant on the completion of the Bhakra Dam project. The township is built on an acquired area of about 800 acres and can be taken over, barring a few houses which will be required for the permanent Bhakra staff, at a fair valuation. During the period of construction of the fertiliser *cum* heavy water factory, certain

amount of additional accommodation, might be required involving inexpensive temporary construction and for this the acquisition of a limited area of extra land may be necessary which, in our view, would in any case be extremely useful and allow room for expansion which is bound to come in no distant future.

(2) There is a very well-equipped and well-organised workshop with a technical training school attached to it for most of which again the permanent organisation of Bhakra Dam would have no use. This workshop can also be taken over by the new factory at a fair valuation and would be a most valuable adjunct of it. The workshop has repair and fabrication facilities which are incomparably better and more extensive than what exist at Sindri and might well serve as a nucleus for the establishment of facilities for the fabrication of heavy chemical plant and machinery in India. There are; similarly, large administrative offices which would be surplus to the requirements of the permanent Bhakra Dam organisation and can in due course serve as the administrative centre of the new factory.

(3) A large body of trained technical personnel is available on the spot which would very considerably facilitate the construction and operation of the new factory. This is an inestimable advantage over an industrially undeveloped location where the necessary personnel will have to be recruited and trained.

(4) Good communication facilities have already been established both by road and by rail which will all come extremely useful for the new factory.

(5) Finally, plenty of excellent sites for the location of the new factory and, if necessary, one or two new neighbourhood units are available in the immediate vicinity of the river and the existing township. The bearing strength of the soil, we have been assured, is not less than 2 tons per square foot which implies that any special precautions over foundations of heavy plants and buildings, involving extra capital investment, would be unnecessary.

Generally speaking, all these represent assets of very considerable value and obviously the best way to utilise them would be to establish a large factory on the spot as a permanent operating unit.

14. Our investigations have not yet made sufficient progress to enable us to cover in this interim review all our terms of reference, for example, an assessment of the requirements of technical personnel for staffing the proposed heavy water *cum* fertiliser plant. We ourselves propose to pursue further many of the points we have mentioned in this note which we have not so far been able to investigate fully; and present, in due course, a reasonably complete project report. We have, nevertheless, considered it expedient to make this interim review mainly with a view to bring to the notice of Government certain firm recommendations which we are, even now, in a position to make so that urgent action can be initiated with respect to them without delay. Since a decision in principle has already been taken to locate one of the new fertiliser units at Nangal, immediate attention to these points will ensure quicker completion of the project. The particular points on which urgent action may profitably be initiated at once in the light of the recommendations made in this note are as follows:

(i) arrangements should be made at once for the installation of the required power generating capacity at Bhakra-Nangal so as to make available to the new fertiliser *cum* heavy water factory

a firm all-the-year-round power supply of round about 160,000 K.W., at a load factor of 90 per cent. We have been given to understand that to establish availability of firm power of this order it will be necessary to supplement the power unit already established at Ganguwal and the one about to be established at Kotla by the installation of 4 generators each of 90,000 K.W., capacity at Bhakra. It is beyond our province to investigate whether all this large installation is really required. We can only recommend that availability of power to the extent indicated above be established at as low a cost as possible keeping in view the prime importance of production of low cost energy for economical production of ammonia by the process that it is unavoidable to adopt if the scheme is linked with production of heavy water;

(ii) simultaneously, a firm rate at which electricity would be supplied should be negotiated without delay with the Bhakra Dam authorities and an agreement concluded well in advance of the initiation of the project. All our conclusions will be completely upset if electrical energy is ultimately charged for at a rate higher than 2.6 pies per unit which in itself is, in our opinion, somewhat too high for the economical operation of a nitrogen factory on the electrolysis process;

(iii) negotiations should be opened from now for the ultimate acquisition of the township along with schools, clubs, markets, administrative offices, hospital, workshop, training institute, etc. etc. to such extent as these facilities will be surplus to the needs of the permanent Bhakra Dam organisation. Similarly, plans should be made from now for the release of trained personnel and their eventual transfer to the new factory organisation according to a mutually agreed time schedule; and

(iv) arrangements be taken in hand for the acquisition of at least 3,000 acres of land. With the establishment of a permanent operating factory, local land values are bound to appreciate; and land purchases by private parties, particularly traders and businessmen, are likely to occur on an increasing scale. Room should be secured, in the circumstances, for the future expansion of the new factory and the township and the need for provision of a sanitary belt all round should be taken care of from now. To avoid speculative purchases, such lands as may even now be tentatively selected should, we suggest, be notified at once under the law relating to land acquisition. We have tentatively selected two alternative sites for the location of the main factory on either side of the river and we suggest that, pending a final decision, both the sites covering between three and four thousand acres might be notified forthwith. A map showing the selected sites is at present under preparation in consultation with the authorities of the Punjab Government and will be submitted as soon as it is ready.

15. We note in the end that on the suggestion of the Atomic Energy Commission we have examined the question of executing the combined heavy water *cum* nitrogen plant project in two stages in order that, if possible, the manufacture of a minimum quantity of heavy water can be established as soon as the necessary quantum of power is available on the partial completion of the main Bhakra Dam. We are convinced, as a result of the investigations we have made, that the plan of completing the project in stages would be uneconomical and inexpedient. Not only would this involve larger capital investment in the end which will adversely affect economic production for all time to come but the resultant gain would have little practical significance. We understand that it will

take nearly the same time to instal a single generator or as many as 4 generators or more at Bhakra. Whether it is decided to instal a single generator or 4 generators, the first generator will be commissioned not earlier than the end of June 1959, provided orders are placed forthwith; and thereafter there will be a time-lag of only three months between the commissioning of one generator and another. In other words, assuming that orders for 4 generators are placed now, the second generator will be commissioned by the end of September 1959, the third by the end of December 1959 and the fourth by the end of March 1960. In these circumstances, we do not see that any material advantage will be gained by planning the execution of the project in stages; and we would accordingly advise against the proposal.

P. M. Nayak,
Secretary.

B. C. MUKHARJI,
Chairman

A. NAGARAJA RAO
Member

M. D. PAREKH
Member

K. C. SHARMA
Member

New Delhi, the 22nd January 1955.

ANNEXURE III—*contd.*

APPENDICES

TO THE

INTERIM REPORT OF THE FERTILIZER PRODUCTION COMMITTEE

APPENDICES

1. Prefatory note

2. Appendix I

    Estimated cost of production of ammonia and ammonium nitrate at Nangal in plants (A) with an annual capacity of 70,000 tons nitrogen; and (B) with an annual capacity of 50,000 tons nitrogen.

3. Appendix II

    Estimated cost of production of ammonium nitrate at Sindri.

4. Appendix III

    Estimated cost of production of nitro-limestone at Nangal in a plant with an annual capacity of 70,000 tons nitrogen.

5. Appendix IV

    Comparative costs of production of ammonia and end product (on a nitrogen basis) at Sindri and Nangal.

PREFATORY NOTE

For a proper appreciation of the attached statements the following explanations are relevant:

(i) The assumed capital costs, though reliable enough for present purposes, are approximate and liable to be revised in our final report. Apart from plant costs, there would be a considerable amount of other expenditure of a capital nature for the proper execution of the project; for example, expenditure on land acquisition, construction of roads, houses, workshops, etc., etc. In Appendices I and III only Rs. 2 and Rs. 2½ crores respectively have been provided on this account to cover certain essential items, but it is almost certain that the total of "other capital expenditure" will be a larger sum. When the entire capital expenditure on the project is taken into account, the production costs now estimated will show a corresponding increase.

(ii) Since it has not yet been possible to select a suitable material for diluting ammonium nitrate, manufacturing costs of pure ammonium nitrate (with 35 per cent nitrogen) and of nitro-limestone (with 20.5 per cent nitrogen) have been calculated for the time being. The production costs per ton of the product finally approved for Nangal will correspond roughly to its nitrogen content; on a nitrogen basis, it will be a more expensive product than pure ammonium nitrate; on the other hand, it will in all probability be less expensive than nitro-limestone on the same basis since (a) the material used as diluent is likely to be less expensive than limestone and (b) the nitrogen content of the product is likely to be higher than 20.5 per cent.

(iii) The capital costs of a plant designed to produce ammonium nitrate with a suitable non-alkaline inert diluent will be somewhat larger than the capital costs assumed for an ammonium nitrate plant and will probably be of the same order as those assumed for a nitro-limestone plant.

(iv) Subject to the explanation furnished in (i) to (iii) above, the total capital costs of an ammonium nitrate plant with an annual capacity of 70,000 tons nitrogen and 7½ tons of heavy water has been estimated to be Rs. 17.9 or Rs. 18 crores; and that for a nitro-limestone plant with identical capacity has been estimated to be Rs. 19.4 or Rs. 19½ crores. These figures include Rs. 2 crores in the case of the ammonium nitrate plant and Rs. 2½ crores in the case of nitro-limestone plant on account "other capital expenditure" referred to in (i) above and an additional Rs. 1 crore for "working capital" in either case.

(v) For Labour and Supervision and general works and administrative overheads we have assumed the total annual charge to be Rs. 60 lakhs for the entire factory, assuming that it will produce nitro-limestone and have the larger capacity of 70,000 tons of nitrogen and 7½ tons of heavy water per year. This is a good deal lower than what Dr. Brun has allowed on this account (Rs. 92 lakhs per year inclusive of insurance, an item not taken into account by us at all) which we think is an over-estimate. The normal expenditure on staff and personnel (including administrative overheads) at Sindri, excluding the Power Plant and the Coke ovens, is of the order of Rs. 60 lakhs per annum. Nangal plant will handle less quantities of solid raw materials and will therefore require fewer personnel; in any case we do not see why expenditure on staff and personnel at Nangal should be any more than what it is at Sindri.

APPENDIX I

(A) COST OF PRODUCTION OF AMMONIA AND AMMONIUM NITRATE AT NANGAL WITH PLANT CAPACITY OF 70,000 TONS NITROGEN PER YEAR.

(1) Cost of production of ammonia—

Capacity of the plant ... 90,000 tons Ammonia per year
7.5 tons heavy water per year.

Cost elements	Annual Cost Rs. lakhs.
Power 1273.5 million Kwhr at 2.6 pies per Kwh ...	172.5
Labour and Supervision	12.0
General Works and Administrative overheads ...	12.0
Auxiliary materials	2.7
Cooling water 90,000 galls. per ton at 0.5 annas per 1000 galls	2.4
Laboratory expenses	0.9
Workshop and instrument services	3.6
Total annual cost ...	395.0
*Capital charges—	
Maintenance materials at 3 per cent of the capital cost of the plant	32.4
Depreciation at 10 per cent of the capital cost of the plant	108.0
Interest at 4.5 per cent	48.5
Total annual cost ...	395.0
Credit for 7.5 tons heavy water at Rs. 10 lakhs per ton ...	75.0
Net Annual Cost	320.0
Cost per ton ammonia	Rs. 356

(2) Cost of production of 100 per cent Nitric Acid—

Capacity 163,000 tons 100 per cent Nitric Acid per year.

Cost elements	Annual Cost Rs. lakhs.
Ammonia 46200 tons at Rs. 365 per ton	164.5
Utilities—	
Power 230 Kwh/ton at 2.6 pies per Kwh	5.05
Condensate and boiler feed 2.2 tons/ton at Rs. 0.4/ton ...	1.43
Cooling water 50,000 galls. per ton at As. 0.5 per 1,000 galls.	2.44
Catalyst at Rs. 3 per ton	4.89
Labour and Supervision	3.0
General Works and Administrative overheads ...	3.0
Workshop and instrument services	1.63
Total annual work cost ...	185.94

* Capital Cost of the plant estimated at Rs. 10.8 crores.

Cost elements	Annual Cost Rs. lakhs.
*Capital Charges—	
Maintenance materials at 3 per cent of the capital cost ...	7.8
Depreciation at 10 per cent of the capital cost ...	26.0
Interest on Capital at 4.5 per cent	11.7
Total annual cost ...	231.44
Cost per ton 100 per cent Nitric Acid	Rs. 142

(3) Cost of production of Ammonium Nitrate—
Capacity 200,000 tons Nitrate per year.

Cost elements	Annual Cost Rs. lakhs.
Nitric Acid 0.815 tons per ton at Rs. 142 per ton ...	232.0
Ammonia 0.217 tons/ton at Rs. 356 per ton ...	154.5
Utilities—	
Power 40 Kwh/ton at 2.6 pies per Kwh.	1.1
Cooling water 6500 galls. per ton at 0.5 annas per 1000 gollons	0.4
Labour and Supervision	8.0
General Works and Administrative Overheads ...	8.0
Workshop	3.0
Laboratory	2.0
Total annual works cost ...	409.0
†Capital Charges—	
Maintenance materials at 3 per cent of the Capital Cost	4.5
Depreciation at 10 per cent	15.0
Interest at 4.5 per cent on 4.5 crores	20.2
Total annual cost ...	448.7
Cost per ton (loose) Nitrate	Rs. 224.3
Bagging charges including bags	16.5
Cost per ton nitrate (Bagged)	Rs. 240.8 or Rs. 241

*Capital Cost of the plant estimated at Rs. 2.6 crores.

†Capital cost of the plant 1.5 crore

Additional capital expenditure ... 2.0 crore

Working Capital ... ... 1.0 crore

(B) COST OF PRODUCTION OF AMMONIA AND AMMONIUM NITRATE AT NANGAL WITH PLANT CAPACITY OF 50,000 TONS NITROGEN PER YEAR

(1) Cost of production of Ammonia

Capacity of the plant 64,500 tons Ammonia per year; 5.4 tons heavy water per year.

Cost elements	Annual Cost Rs. lakhs.
Power 920 million Kwhrs at 2.6 pies per Kwh	124.5
Labour and Supervision	10.8
General Works and Administrative Overheads ...	10.8
Auxiliary Materials	1.93
Cooling water 90,000 galls, per ton at 0.5 annas per 1,000 galls.	1.74
Laboratory expenses	0.90
Workshop and instrument services	3.60
Total Annual Works Cost ...	154.27
*Capital Charges—	
Maintenance materials at 3 per cent of the Capital Cost of the plant	24.60
Depreciation at 10 per cent	82.0
Interest at 4.5 per cent	36.8
Total Annual Cost ...	297.67
Credit for 5.4 tons heavy water at Rs. 10 lakhs per ton ...	54.0
Net Annual Cost ...	243.67
Cost per ton Ammonia	Rs. 378

(2) Cost of production of Nitric Acid—

Capacity of the plant 117,000 tons per cent Nitric Acid per year.

Cost elements	Annual Cost Rs. lakhs.
Ammonia 33,200 tons at Rs. 378 per ton	125.5
Utilities—	
Power 230 Kwh/ton at 2.6 pies per Kwhr	3.11
Condensate and boiler feed 2.2 tons/ton at Rs. 0.4 per ton	1.03
Cooling water 50,000 galls. per ton at 0.5 annas per 1,000 gallons	1.63
Catalyst	3.51
Labour and Supervision	3.0
General Works and Administrative Overheads ...	3.0
Workshop and instrument services	1.63
Total Annual Works Cost ...	162.41

*Capital cost of the plant estimated at Rs. 8.2 crores.

Cost elements	Annual Cost Rs. lakhs.
*Capital Charges—	
M/ce at 3 per cent of the Capital Cost	5.90
Depreciation at 10 per cent	19.70
Interest at 4.5 per cent	8.85
Total Annual Cost ...	176.86
Cost per ton 100 per cent Nitric Acid ...	... Rs. 151

(3) Cost of production of Ammonium Nitrate—
Capacity of the plant 143,000 tons Nitrate per year.

Cost elements	Annual Cost Rs. lakhs.
Nitric Acid 0.815 tons per ton at Rs. 151 per ton ...	176.0
Ammonia 0.217 tons per ton at Rs. 378 per ton ...	117.0
Utilities—	
Power 40 Kwh/ton at 2.6 pies per Kwh.	0.77
Cooling water 6.500 galls/ton at 0.5 an. per 1,000 galls	0.29
Labour and Supervision	8.0
General Works and Administrative Overheads ...	8.0
Workshop	3.0
Laboratory expenses	2.0
Total Annual Cost ...	315.06
†Capital Charges—	
M/ce materials at 3 per cent of the Capital cost of plant	3.45
Depreciation at 10 per cent	11.50
Interest at 4.5 per cent on 4.15 crores	18.60
Total Annuel Cost ...	348.61
Cost per ton (loose) Nitrate	... Rs. 243.7
Bagging Charges	... Rs. 16.5
Cost per ton bagged Nitrate	... Rs. 260.2

*Capital cost of the plant estimated at Rs. 1.97 crores.

†Capital Cost of the plant including storage and bagging estimated at Rs. 1.15 crores.

Cost of general Works	2.0 crores.
Working Capital	1.0 crore.

APPENDIX II

COST OF PRODUCTION OF AMMONIUM NITRATE AT SINDRI

Capacity 200,000 tons Ammonium Nitrate per year 163,000 tons 100 per cent Nitric acid per year.

(1) Cost of production of Nitric Acid

Cost elements	Annual Cost Rs. Lakhs.
Ammonia 46,200 tons at Rs. 346/ton	160.0
Utilities—	
Power 230 kwh/ton at 8 pies per kwh.	15.6
Condensate and boiler feed 2.2 tons per tons at Rs. 0.8/ ton	2.86
Cooling water (make up) 5,000 galls./ton at Rs. 1.8/1000 gallons	2.86
Catalyst at Rs. 3/ton	4.89
Labour and Supervision	3.0
General Works and Administrative Overheads ...	3.0
Workshop and Instrument Services	1.63
Total operating charges per year ...	205.21
*Capital Charges—	
Maintenance materials at 3 per cent of the Capital Cost	7.80
Depreciation at 10 per cent of the Capital cost ...	26.0
Interest at 4.5 per cent on the investment	11.7
Total Annual Cost ...	251.18

Cost per ton 100 per cent Nitric Acid ... ... Rs. 154

(2) Cost of production of ammonium nitrate—

Cost elements	Annual Cost Rs. Lakhs,
Nitric Acid 0.815 tons/ton at Rs. 152.5 per ton ...	251.0
Ammonia 0.217 tons/ton at Rs. 346 per ton	150.0
Utilities—	
Power 40 Kwh/ton at 8 pies per kwh	3.32
Cooling water (make up) 650 gallons/ton at Rs. 1.8/ 1,000 gallons	2.34
Labour and Supervision	8.0
General Works and Administrative Overheads ...	8.0
Workshop	3.0
Laboratory Services	2.0
Total Annual Works Cost ...	427.66

*Capital cost of the plant Rs. 2.6 crores (same as at Nangal).

Cost elements	Annual Cost Rs. lakhs.
*Capital Charges—	
· Depreciation at 10 per cent of the Capital cost (1.5 crore)	4.50
Depreciation at 10 per cent of the Capital cost (1.5 crore)	15.0
Interest at 4.5 per cent on Rs. 4.5 crore	20.2
Total Annual Cost ...	467.36
Cost per ton (loose) Nitrate	233.18
Bagging charges including bags	16.50
Cost per ton nitrate (bagged)	Rs. 249.68 or say Rs. 250

* Capital Cost assumed same as at Nangal.

APPENDIX III

COST OF PRODUCTION OF NITRO-LIMESTONE AT NANGAL WITH PLANT CAPACITY OF 70,000 TONS NITROGEN PER YEAR

Capacity 340,000 tons Nitro-limestone (20.5 per cent N) per year.

Cost elements	Annual Cost Rs. lakhs.
Nitric Acid 163,000 tons at Rs. 142/ton	232.0
Ammonia 43,400 tons at Rs. 356/ton	154.5
Limestone 140,000 tons/year at Rs. 10 per ton ...	14.0
Utilities—	
Power 50 Kwh/ton at 2.6 pies per Kwh	2.33
Cooling water 4,000 galls/ton at 0.5 annas per 1,000 galls.	0.40
Labour and Supervision	15.0
General Works and Administrative Overheads ...	15.0
Workshop	6.0
Laboratory	3.0
Total Annual Works Cost ...	442.23
*Capital Charges—	
Maintenance materials at 3 per cent of the Capital cost	7.50
Depreciation at 10 per cent of the capital cost ...	25.0
Interest at 4.5 per cent on Rs. 6 crores	27.0
Total Annual Cost ...	501.73
Cost per ton (loose) Nitro-chalk	Rs. 148.0
Bagging charges including bags	Rs. 16.5
Cost per ton Nitro-chalk (bagged)	164.5

* Capital cost of the plant 2.5 crores.
Additional Capital expenditure ... ... 2.5 Crores.
Working Capital ... ... 1.0 Crore.

APPENDIX IV

COMPARATIVE COSTS OF PRODUCTION OF (A) AMMONIA AND (B) END PRODUCTS ON A NITROGEN BASIS

Location & size of the factory	Cost per ton ammonia	Cost per ton Nitrogen in		
		Ammonium nitrat	Nitro-limestone	Ammonium sulphate
	Rs.	Rs.	Rs.	Rs.
1 .Sindri (70,000 tons/year N)	346	715	..	1,050
2. Nangal—				
(a) in a 50,000 tons N/year plant ..	378	750	..	..
(b) in a 70,000 tons N/year plant.. ..	356	690	800	..
(c) in a 50,000 tons N/year plant according to Dr. Brun's estimate.	397	..	1,083	..

ANNEXURE IV

A FERTILISER PLAN FOR 1956—61

1. With the completion of some of the river valley projects and a number of minor irrigation schemes, large areas of dry farm land (nearly 20 million acres) will be brought under irrigation by 1956. The maximum benefits of irrigation can, however, be obtained only if it is judiciously applied in combination with bulky organic manures and chemical fertilisers. There are thus almost unlimited possibilities of increasing agricultural production through greater emphasis on the use of fertilisers in irrigated farming. In this note an attempt will be made to assess our requirements of fertilisers during the Second Five Year Plan period, *i.e.*, 1956—61.

Imports, production and consumption of fertilisers

2. In the past, several types of nitrogenous and phosphatic fertilisers have been tested by the Agricultural Departments, and ammonium sulphate and superphosphate are the most commonly used in the country today. However, the need of phosphates is not generally recognised, and their consumption at present is mostly in the form of small quantities of mixed fertilisers used on vegetables, potatoes, paddy, etc. The following statement shows the imports and internal production of ammonium sulphate, superphosphate and potash since 1937:—

Year	Ammonium sulphate		Superphosphate		Potassic fertilisers	
	Imports (tons)	Production (tons)	Imports (tons)	Production (tons)	Imports (tons)	Production (tons)
1937	53,260	Not known	7,405	..	4,534	*Not known
1938	..	Do.	6,788	..	2,794	Do.
1939	79,992	Do.	..	..	..	Do.
1940	..	Do.	..	..	..	Do.
1941	..	Do.	2,722	..	100	Do.
1942	1,361	Do.	..	..	696	Do.
1943	..	Do.	148	..	1,258	Do.
1944	..	Do.	1,572	..	597	Do.
1945	69,260	Do.	901	..	1,493	Do.
1946	..	22,459	60	4,500	1,288	Do.
1947	..	21,278	380	5,000	3,023	Do.
1948	1,33,183	35,210	1,000	21,358	1,931	Do.
1949 ..	1,70,839	45,935	248	50,641	4,067	Do.
1950	3,70,024	47,304	350	52,432	9,620	Do.
1951	1,04,000	52,704	2,615	61,018	13,150	Do.
1952	2,27,000	2,20,368	2,079	‡46,650	5,255	Do.
1953	1,03,300	†3,18,491	6,829	‡48,294	14,408	Do.

* It is reported that from 1,000 to 2,000 tons of muriate of potash are produced annually in the country.

† Provisional.

‡ Low production due to discontinuance of phosphate Pool.

3. The figures of consumption of ammonium sulphate and superphosphate are available only from 1949 onwards, and are given below:—

Year	Ammonium sulphate (tons)	Super-phosphate (tons)
1949	2,80,000	Not known
1950	2,75,000	Not known
1951	2,93,353	43,311
1952	2,76,253	28,705
1953	4,20,800*	25,000†

* Includes estimated consumption for Bombay, Orissa and Punjab.

† Based on returns of consumption received from 12 States only.

N.B.—Figures of consumption of potash not available.

Requirements of nitrogenous fertilisers

4. In 1953, Dr. F. W. Parker and Dr. J. M. Blumo, in their note on "Fertiliser Programme in India", estimated the potential fertiliser requirements of this country as 1,000,000 tons of nitrogen and 5,00,000 to 1,000,000 tons of phosphorus (P_2O_5). The basis of this calculation is not known. They also suggested certain targets of consumption of nitrogen and phosphate for the period 1953 to 1960, which are reproduced below:—

Year	Nitrogen (tons)	P_2O_5 (tons)
1953	1,00,000	10,000
1954	1,20,000	25,000
1955	1,40,000	41,666
1956	1,70,000	58,333
1957	2,00,000	75,000
1958	2,30,000	91,666
1959	2,60,000	1,08,333
1960	3,00,000	1,25,000

5. In 1954, the Standing Committee on Manures and Fertilisers of the Government of India framed estimates of fertiliser consumption in the country for the period 1953-54 to 1960-61. These estimates are as under:—

Year	Nitrogen (tons)	P_2O_5	K_2O
1953-54	1,00,000	12,000	6,000
1954-55	1,35,000	18,000	8,000
1955-56	1,75,000	25,000	10,000
1956-57	2,10,000	40,000	12,000
1957-58	2,50,000	60,000	15,000
1958-59	3,00,000	85,000	20,000
1959-60	3,60,000	1,20,000	25,000
1960-61	4,35,000	1,50,000	30,000

5.1. The Committee was of the view that the targets of fertilisers consumption framed by it were capable of achievement, provided the following steps were taken:—

(a) Efficient distribution arrangements should be made so as to make fertilisers available to the cultivators in time and without the cultivators having to go long distances for procuring them. For this purpose depots should be established all over the country for the storage and distribution of fertilisers.

(b) In the Community Project areas and the National Extension Blocks, each village level worker should be in charge of a plot for demonstrating the usefulness of fertilisers in increasing crop production.

(c) A favourable price relationship between fertilisers and crops should be established and maintained for a few years so as to make it profitable for the cultivators to use fertilisers, on an extended scale.

(d) Cheap and easily available credit should be given to cultivators. This credit should invariably be given in kind and not in cash. Arrangements for grant of credit should be completed every year before the end of May, so that cultivators may be able to procure in time their requirements of fertilisers for application to crops.

(e) Government should make available every year, free of cost, some quantities of fertilisers for trial with a view to demonstrating the profitableness of fertilisers use in crop growing.

6. As both Dr. Parker and the Standing Committee on Manures and Fertilisers have not indicated as to how the estimates of fertiliser requirements framed by them were arrived at, it appears necessary to determine to what extent these figures can be relied upon. There are two ways of assessing the fertiliser requirements during the Second Five Year Plan period. One method would be to base the estimates on the additional foodgrain production to be obtained by manuring, and the other could be related to certain proportions of the irrigated and assured rain-fall areas

which should be manured to increase production. The estimates of fertiliser requirements calculated by both these methods are given below:

(a) *Estimates of fertiliser requirements based on additional foodgrain production by manuring*

7. In the first Five Year Plan the target of additional production of foodgrains to be achieved by 1956 has been fixed at 7.6 million tons on the basis of 13.7 oz. per adult per day. Assuming that this target will be achieved and calculating the consumption of foodgrains on the basis of 14. oz. per adult per day, the additional quantity of foodgrains needed to meet the shortfall in 1960-61 due to increase in population will be as per statement below:—

1. Estimated population (Millions)	1956 1961	377·60 *410·00
2. Estimated adult equivalent population at 86% (Millions) ..	1956 1961	324·74 353·00
3. Production of foodgrains (including pulses) (Million tons) ..	1956	61·60
4. Requirements of foodgrains for consumption, seeds, etc. in 1961 (million tons)		
(*i*) on the basis of 14 oz. of cereals per adult per day ..	50·30	
(*ii*) on the basis of 8 oz. of pulses per adult per day ..	10·80	
(*iii*) on the basis of 20 % of total pulses production (9·4 million tons) for stock feeding	1·90	
(*iv*) add 1/7 of (*i*) & (*ii*) on account of seed, wastage, etc.	8·71	
	71·71	71·71
5. Shortfall in foodgrains compared to production at the 1956 level (million tons)—		
Requirement in 1961	71·71	
Production in 1956	—61·60	
*Based on the Census Commissioner's estimate	10·11	10·11

7.1. The total area under cultivation in the country is 326 million acres. Of this area, 250 million acres are under foodgrain crops, *i.e.*, cereals, millets and pulses. This area will produce the additional quantity of 10.11 million tons of foodgrains needed to meet the shortfall due to increase in population and the provision of a higher standard of nutrition. The remaining area of 76 million acres grows many heterogenous crops, such as, oilseeds, sugarcane, cotton, jute, vegetables, fruits etc. The nitrogen requirements of these crops cannot be as readily calculated by a common formula as those of foodgrain crops, which give an increase of 10 units of foodgrains for a unit of nitrogen applied. For the purpose of estimating the nitrogen requirements of heterogenous crops, we may convert the production from 76 million acres (annually under heterogenous crops) into foodgrain equivalents on the basis of one-third of a ton of foodgrains to an acre of land. By adopting improved methods of cultivation, we may aim at a modest figure of additional production, in 1961, of 10 per cent more in terms of foodgrain equivalents than the converted 1956 level of production. The figures of production are given below:—

(i) Converted production in 1956 from 76 million acres, estimated in terms of foodgrain equivalents at 1/3 ton per acre (million tons)	25.30
(ii) Target of additional production in 1961 calculated at 10 per cent of (i) above	2.53

7.2. The additional production of foodgrains in 1961 will thus be 12.64 million tons. It includes 10.11 million tons needed to meet the short-fall due to increase in population in 1956—61 the converted additional production (2.53 million tons) from about 76 million acres annually under heterogenous crops. This total additional production will be the resultant of all

improved and intensive methods of cultivation, such as, the use of improved seed, irrigation, manuring, reclamation of waste land, control of insect pests and plant diseases etc. As a safe estimate, we may assume that 20 per cent of the additional production to meet the short-fall of 12.64 million tons of foodgrains and equivalents can be realised by the use of fertilisers. On the basis that one unit of nitrogen gives an increase of 10 units of foodgrains, the quantity of nitrogen required to produce an additional 2.53 million tons (1/5 of 12.64 million tons) of foodgrains and equivalents will be 0.253 million tons. The requirement of nitrogen in 1961 will, therefore, be 0.253 million tons over and above the actual consumption of nitrogenous fertilisers in 1956. It is difficult to estimate the consumption of nitrogen in 1956, but, considering the trend of consumption in the current year, it may not be unreasonable to assume a consumption of 0.12 million tons of nitrogen. The *total* requirement of nitrogen in 1961 will thus be 0.373 million tons, or 18,65,000 tons in terms of ammonium sulphate.

(b) *Estimate of fertiliser requirements based on irrigated and assured rainfall areas*

8. Commercial crops like sugarcane, potato and tobacco; plantation crops like coffee and tea, and cereals, in particular paddy, respond very favourably to the application of fertilisers. Data regarding the areas under different crops, which receive nitrogenous fertilisers at present, are not readily available. For the second Five Year Plan, however, it is necessary that for each important crop or a group of crops specific targets of nitrogen consumption should be laid down. An estimate of these targets and of the total requirements of nitrogen in 1961 is given in the statement below:—

Crop	Total area (million acres)	Percentage area to be manured	Area to be manured (Million acres)	Dose in terms of nitrogen per acre (lb)	Requirements in terms of Nitrogen (million tons)
Sugarcane	4·40	25	1·10	100	0·048
Potatoes	0·60	25	0·15	70	0·005
Cotton	*2·00	25	0·05	30	0·006
Tobacco	0·80	33	0·26	40	0·005
Other irrigated crops	†60·00	25	15·00	20	0·200
Paddy	‡55·00	20	11·00	20	0·100
Coffee and tea ..	1·00	..	..	..	0·015
				Total ..	0·379
Deduct—quantities likely to be used in 1955-56			..	..	0·120
Net additional quantity required in 1961				..	0·259

*Relates to irrigated areas under American varieties (out of 16 million acres under cotton and future extension of area under Bhakra-Nangal, Tungbhadra and Kakrapara river valley projects).

† Total area under irrigated crops in 1956 is estimated to be 70 million acres; from this deduct 10 million acres under sugarcane, potatoes, cotton, tobacco and other irrigated commercial crops, leaving 60 million acres under other crops.

‡ Total area under paddy is 75 million acres; from this deduct 20 million acres under *irrigated* paddy, leaving 55 million acres under *rain-fed* paddy. About 50 per cent of 55 million acres is under assured rainfall. 40 per cent of assured rainfall area, or 20 per cent of total rainfed area, under paddy will be manured.

9. We may now compare our estimate of the total requirements of nitrogen in 1961 with the estimates framed by Dr. Parker and the Standing Committee on Manures and Fertilisers. If the consumption of nitrogen in 1956 calculated according to these estimates is deducted from the corresponding estimates for 1961, the net requirement of nitrogen during the second Five Year Plan period will be obtained. These figures are given in the statement below:—

	Dr. Parker's estimate	Standing Committee's estimate	Estimate based on	
			Foodgrain production	Irrigated and assured rainfall areas
Requirements of nitrogen (tons)—				
1961	3,00,000	4,35,000	3,73,000	3,79,200
1956	1,70,000	1,75,000	1,20,000	1,20,000
1956—1961 (net requirement) ..	1,30,000	2,60,000	2,53,000	2,59,200

9.1. It would be observed that our estimate of the net requirement of nitrogen during the period of the Second Five Year Plan closely approximates to the estimates made by the Standing Committee on Manures and Fertilisers. As Dr. Parker was a member of the sub-committee of the Standing Committee on Manures and Fertilisers which prepared the estimate of nitrogen requirements in 1956—61, his earlier estimates of lower consumption of nitrogen and phosphorus during the same period (*vide* the note entitled "Fertiliser Programme in India)" were considered by him as "minimum goals" which, if possible, should be "revised upward".

10. Based on our estimate, a phased programme of consumption of nitrogenous fertilisers during the period of the Second Five Year Plan is given below:—

	Nitrogen (tons)
1956-57	150,000
1957-58	190,000
1958-59	240,000
1959-60	300,000
1960-61	370,000

Requirements of phosphatic fertilisers

11. The consumption of phosphatic fertilisers in this country is limited mainly because the application of phosphates to the soil does not yield as spectacular results as the application of nitrogen. However, it is now generally recognised that phosphates are necessary for sustaining increase in crop yields and for maintaining soil fertility at a high level. As shown in statement in para 2 above, the production of superphosphate in 1953 was 48,294 tons, and the imports during the same period were 6,829 tons. When the phosphate pool was formed in this country, the consumption of superphosphate began to increase until it reached the figure of 43,311 tons in 1951-52. With the discontinuance of the phosphate pool the consumption of superphosphate has been steadily going down, and it is not likely to exceed 30,000 tons during the current year. Unless phosphatic fertilisers are liberally subsidised for some time to come, the cultivators in this country are not likely to make increased use of these fertilisers,

which, as stated above, are necessary for building up soil fertility. Assuming that a subsidy on a liberal scale will be available for the distribution and use of phosphatic fertilisers, the following programme of superphosphate consumption in the Second Five Year Plan period is indicated:—

	Tons
1956-57	50,000
1957-58	60,000
1958-59	80,000
1959-60	100,000
1960-61	120,000

N. B.—It is assumed that the consumption of superphosphate in 1955-56 will be 40,000 tons.

11.1. In making the above recommendations regarding the requirements of superphosphate during 1956-61, we have taken into account the installed capacity for superphosphate production in this country, which is about two lakh tons of single superphosphate. Recently, Messrs. Dharamsi Morarji Chemical Company, Bombay, have started producing small quantities of double and triple grades of superphosphate. Thus, the requirements of superphosphate can be easily met from the production in the country, and if adequate propaganda is done and subsidy given on a liberal scale, it is likely that the figures of consumption estimated by us for 1960—61 may be exceeded.

Requirements of potash fertilisers

12. It is a general belief that Indian soils are well provided with potash, and accordingly the Agricultural Departments have not made any attempts in the past to extend the use of potash fertilisers. Recent trials carried out in Bihar, however, have indicated that there are certain areas in the country where the application potash results in increased yields of food crops. At present most of the potassic fertilisers produced in or imported into the country are used for application to plantation corps, such as coffee, tea, coconut etc. If as a result of trials now in progress and proposed to be conducted in cultivators' fields in 1956—61, potash deficiencies in the soils are found to occur over large areas, a planned programme of consumption will be prepared if necessary. In the present circumstances, there is little likelihood of an increased consumption of potassic fertilisers on foodgrain crops.

Agronomical and storage trials

13. In 1953, agronomical experiments were undertaken to test the response of paddy and wheat to the application of fertilizers. The fertilisers used in these trials were—

Ammonium Sulphate	Urea.
Ammonium Nitrate	Ammonium phosphate.
Nitrophosphate	Triple superphosphate.

These experiments are being conducted at 40 different centres in the country under varying conditions of soil-climate complex. The object of these experiments is to ascertain whether there is any difference in the response of paddy or wheat to different forms of nitrogenous and phosphatic fertilisers. Storage trials with these fertilisers are also being conducted at 20 different centres in the country with a view to obtaining information on the suitability of packing material, and the keeping qualities of these fertilisers under varying climatic conditions.

14. Results of the agronomical experiments indicate that urea and ammonium nitrate are as efficient as ammonium sulphate as regards their

effect on wheat and paddy. There is no reason to believe that these three fertilisers will behave differently towards other crops. Of the two compound fertilisers, ammonium phosphate was decidedly better than nitrophosphate. Triple superphosphate is a good phosphatic fertiliser and, as it contains about 45 to 46 per cent P_2O_5 against 16 per cent of P_2O_5 in single superphosphate, it has a distinct advantage over the latter in the cost of transport.

15. Results of storage trials obtained so far with the above fertilisers may be summarised as under:—

(i) Ammonium Sulphate and ammonium phosphate have the best keeping quality. Ammonium phosphate does not form lumps in storage and retains its granular form. Ammonium sulphate sometimes "cakes", but its lumps can be easily broken.

(ii) Both urea and ammonium nitrate are deliquescent, *i.e.*, absorb moisture on standing. Ammonium nitrate is worse than urea in this respect. Although both urea and ammonium nitrate used in storage trials were in prilled form, their physical condition deteriorated with increasing humidity.

(iii) Nitrophosphate readily absorbs moisture and has a very poor keeping quality.

(iv) Triple superphosphate does not absorb much moisture on standing, but, as it contains free acid, the packing material deteriorates rapidly.

16. The packing materials used in the storage trials were: (1) ordinary gunny bags, (2) moisture-proof paper bags inside ordinary gunny bags, and (3) alkathene bags inside ordinary gunny bags. All fertilisers kept well in alkathene-lined gunny bags. The paper-lined gunny bags were the next in order in this respect. Ammonium sulphate and ammonium phosphate can be stored without much difficulty in ordinary gunny bags.

Recommendations

(a) *Choice of a suitable fertiliser or fertilisers for internal production*

17. For a proper understanding of the factors determining the choice of an all-purposes fertiliser or fertilisers for particular crops or particular types of soil, information regarding the characteristics of some important nitrogenous and phosphatic fertilisers which are likely to be useful in the country, is given below:—

(i) *Ammonium sulphate*—It is the most widely used fertiliser in the country and has been found to be useful on a wide variety of soils and crops. It is a crystalline product and contains 20-21 per cent of nitrogen, the whole of which is in water-soluble form. It keeps well in storage and can be handled without much difficulty. It, however, produces acidity in the soil. It is, therefore, necessary to apply lime at the rate of half a ton to one ton per acre intervals of two or three years, when ammonium sulphate is used on acid soils. If applied in conjunction with bulky organic manures, it can be used on all types of soil without producing any harmful effects.

(ii) *Urea*—It contains 44—46 per cent of nitrogen. A few days after its application to the soil, it changes into ammonia form and behaves more or less like sulphate of ammonia. It produces acidity in the soil to a comparatively less extent than does ammonium sulphate. As it is likely to be leached out from the soil, it should not be applied when the soil contains free water or is likely to remain wet for three or four days after application.

Trials in this country have shown that it is as efficient as ammonium sulphate on an equal nitrogen basis. It should, however, be preferred to the latter in areas where crops are grown under controlled irrigation and when there is no danger of the fertiliser being leached out from the soil due to rains or floods being experienced within two days after application. It presents a serious problem of storage in humid areas as it absorbs moisture very readily when the relative humidity rises above 75 per cent. It is a cheap source of nitrogen as it has a distinct advantage over ammonium sulphate in the cost of transport.

(iii) *Ammonium nitrate*—It contains 38 per cent of nitrogen (½ ammoniacal nitrogen and ½ in nitrate form). It is completely soluble in water and contains both the ammoniacal and nitrate forms of nitrogen which are readily taken up by the plant. It tends to make the soil acid but less so than ammonium sulphate. As part of the nitrogen in this fertiliser is in the form of nitrate, it is more susceptible to leaching than ammonium sulphate. It would indeed be the ideal fertiliser but for two serious drawbacks—it is deliquescent, tending to set in a hard mass and it may explode. To overcome these drawbacks, in England it is mixed with calcium carbonate and marketed under the trade name of nitrochalk. The calcium carbonate content of nitrochalk makes it suitable for soils low in lime. The Indian Fertiliser Mission have stated in their report that nitro-chalk would be "suitable for those areas in India where dry farming is the normal practice and high humidity conditions are absent and also perhaps, for winter crops in wet farming areas". While we may recommend the use of nitrochalk in these areas because of low humidity, the soils of these areas are generally rich in lime and will not react favourably to the application of nitro-chalk. In the U.S.A., ammonium nitrate is produced in prilled form, in which case the granules are protected by a light coating of oil and Kieselgurh. This form greatly improves the physical condition of ammonium nitrate but does not make it completely hazard-free.

(iv) *Ammonium sulphate-nitrate*—It contains 26 per cent of nitrogen (19.5 per cent as ammoniacal nitrogen and 6.5 per cent in the nitrate form). Like ammonium sulphate, this fertiliser has good keeping quality, is entirely non-hazardous and produces an equally good effect on most of the crops. It produces less acidity on application to the soil than does ammonium sulphate and to that extent should be preferred to the latter. The manufacture of ammonium sulphate-nitrate in preference to ammonium sulphate will reduce the drain on the high grades of gypsum, which is available in limited quantities in the country, used in the manufacture of ammonium sulphate, and will place on the market a fertiliser which is as efficient as ammonium sulphate but less harmful than the latter in acid soils.

(v) *Ammonium chloride or muriate of ammonia*—It is a white crystalline compound with a nitrogen content of about 26 per cent. It possesses an excellent physical condition. It is reported to be unsuitable for certain crops such as tobacco, citrus fruits and potatoes. but it is extensively used on paddy in Japan. It has so far found only an industrial use in this country. In general it resembles sulphate of ammonia, but it produces slightly less acidity in the soil than the latter. Its use as a fertiliser on crops grown in this country is being investigated, but it is not likely to find an extensive application unless it can be produced at a particularly low cost.

(vi) *Ammonia*—It is a gas containing about 80 per cent of nitrogen. When compressed under suitable conditions of pressure and temperature, it becomes liquid, in which form it is known as anhydrous ammonia, Another form, aqueous ammonia, results from the absorption of ammonia gas in water, in which it is quite soluble. Anhydrous ammonia is usually stored and transported in cylinders. Ammonia is used as a fertiliser in both these forms. For applying it to the soil in anhydrous form, special equipment is required and this makes its application costly. Recently, some trials have been conducted in Mysore, which indicate that it is possible to use anhydrous ammonia as a fertiliser with the help of simple, improvised equipment. Anhydrous ammonia can also be applied by dissolving the gas in irrigation water. Although anhydrous ammonia is a good fertiliser, its use in this country is not likely to extend beyond the areas in the neighbourhood of manufacturing centres because of the high cost involved in its transport. As aqueous ammonia, it has recently been tried in the fertilisation of cotton on the Surat Agricultural Station in the Bombay State. Aqueous ammonia was poured through funnels fastened securely to the bowl of the seed-drill, and measured quantities of the fertiliser were applied uniformly to rows of cotton at the rate of 15 and 30 lbs. of nitrogen per acre. Men walking behind the seed-drill closed the furrows with the soil by trampling it under their feet. This experiment has shown that aqueous ammonia is as efficient as ammonium sulphate as a nitrogenous fertiliser for the cotton crop. Ammonia produces less acidity in the soil than sulphate of ammonia.

(vii) *Ammonium phosphate*—There are two forms of ammonium phosphate, *viz.*, monoammonium phosphate and diammonium phosphate. Monoammonium phosphate contains 11 per cent of nitrogen and 48 per cent of available phosphoric acid. Diammonium phosphate contains 21 per cent of nitrogen and 53 per cent of available phosphoric acid. Both the forms are soluble in water. Ammonium phosphate possesses an excellent mechanical condition, and trials with various crops carried out in this country have shown it to be a dependable fertiliser.

(viii) *Superphosphate*—It is a phosphatic fertiliser prepared from rock phosphate and sulphuric acid. It contains about 16—20 per cent of water-soluble phosphoric acid. It also contains some free acid which is responsible for the rotting of bags in which it is packed. The fertiliser should be stored in dry condition as far as possible to reduce the damage to gunny sacking. It is a suitable source of phosphorus for all crops. It should not be used in red or lateritic soils as these soils usually contain active iron and aluminium compounds which fix the phosphorus and render it unavailable to crops. In such cases, other phosphatic fertilisers like bone-meal, rock phosphate or basic slag may be used.

(ix) *Triple superphosphate*—It contains 40—45 per cent of water-soluble phosphoric acid. It has a greater tendency to "cake" than single superphosphate. To overcome this drawback, triple superphosphate is now being produced in a granular or prilled form. It is as efficient a source of phosphorus as single superphosphate, but contains larger quantities of phosphorus.

18. Field experiments conducted in the last *kharif* and *rabi* seasons have established the suitability of urea and ammonium sulphate as all-purposes fertilisers. Similar trials are now being conducted with ammonium sulphate-nitrate, and, although there is no reason to doubt that it will

react differently from the above two fertilisers, it is decidedly superior to ammonium sulphate in its effect on soils. The suitability of an all-purposes fertiliser will also have to be judged in the light of its keeping quality and ease of handling and transport. When all these facts are considered, the conclusion seems to be obvious that ammonium sulphate-nitrate is perhaps an excellent fertiliser whose production also may not offer any difficulties in view of the fact that Sindri is already manufacturing large quantities of ammonium sulphate, which is one of the components of this fertiliser. Nitrochalk, which is a physiologically neutral product, will be a good fertiliser for the paddy crop in acid soils, but, as it has a poor keeping quality, it cannot be recommended for heavy rainfall areas where paddy is generally grown. As regards urea, its only serious drawback is its poor keeping quality under humid conditions, and, unless it is manufactured in prilled form, it will not be suitable for the heavy rainfall areas. It will, however, prove to be an excellent fertiliser in the dry areas of the country both for the *kharif* and *rabi* crops grown under controlled irrigation.

19. With the exception of bone-meal, the phosphatic fertiliser, which is produced in quantity in the country, is single superphosphate (16 per cent P_2O_5). Under the present conditions of demand for phosphatic fertilisers, the internal production of superphosphate will adequately meet our requirements during the period 1956—61. Its manufacture, however, should be left in private hands as at present. When the demand for phosphatic fertilisers grows, it may then be necessary to consider whether any other more suitable types of phosphatic fertilisers should be manufactured in the country. These fertilisers are ammonium phosphate and dicalcium phosphate. The production of ammonium phosphate in the country will become possible when cheap electric energy is available on the completion of some of the hydro-electric projects. The manufacture of dicalcium phosphate can also be undertaken in due course since raw materials for its manufacture are available in the country. However, the question of internal production of ammonium phosphate or dicalcium phosphate is not likely to arise in the Second Five Year Plan period.

(b) *Increasing internal production*

20. The internal production of nitrogenous fertilisers has already become inadequate to meet consumption requirements, and resort is being had to imports to make up the shortfall in the current year's needs. If the prices of foodgrains can be stabilised at a reasonable level, the demand for nitrogeous fertilisers is likely to grow at a more rapid pace than was anticipated a few years ago, thanks to the propaganda for increasing paddy yields by the application of high doses of nitrogenous fertilisers, and the removal of control on the movement of foodgrains in the country. There is now a strong case for setting up one or two fertiliser factories to meet the country's increased requirements.

20.1. The new factory should manufacture ammonium sulphate-nitrate in view of the excellence of this fertiliser for almost all types of soil. There is an equally good case for the manufacture of urea, but, in view of its property to deteriorate under humid conditions, its use will generally be restricted to crops grown under controlled irrigation in north India, or the comparatively dry areas of the river valley projects in the Deccan, e.g. the Tungabhadra project, the Bombay Deccan Canals, etc.

Conclusions

21. In para 4 above, we have referred to the estimates framed by Drs. Parker and Blume regarding the potential fertiliser requirements of this country as one million tons of nitrogen and about half a million tons of phosphorus (P_2O_5). The figures worked out by us for the Second Five

Year Plan come to 0.37 million tons of nitrogen and 0.02 million tons of phosphorus, or 18.5 lakh tons of ammonium sulphate and 1.2 lakh tons of superphosphate. Although our estimates are about 26 per cent of Dr. Parker's figures, they will exceed the 1956 level of consumption by 12.5 lakh tons in terms of ammonium sulphate and 0.8 lakh tons as superphosphate. The total additional requirement of chemical fertilisers, therefore, comes to 13.3 lakh tons. These estimates may be compared with fertiliser consumption in other countries. The figures of fertiliser consumption in the U.S.A. from 1910 to 1950 are given in the statement below:—

(*In million metric tons*)

Year	Quantities distributed	Indices		
		Base year 1910	Base year 1930	Base year 1940
1910	5·5	*100·0*	65·5	63·2
1915	5·4	98·2	64·3	62·1
1920	7·3	132·7	86·9	83·9
1925	7·5	136·4	89·9	86·2
1930	8·4	152·7	*100·0*	96·5
1935	8·5	118·2	77·4	74·7
1940	8·7	158·2	103·6	*100·0*
1945	14·0	254·5	166·7	160·9
1950	19·8	360·0	235·1	227·6

21.1. The following points in the above statement are worthy of note:—

(a) Fertiliser consumption in the U.S.A. has increased by 14.3 million tons in 40 years from 1910—1950.

(b) The use of fertilisers has gone up from 8.7 million tons to 19.8 million tons in ten years from 1940 to 1950. This shows a remarkable increase of over 11 million tons in a single decade.

21.2. Against this experience of the U.S.A., the additional requirements of chemical fertilisers estimated by us are only 13.3 lakh tons. The implementation of even this modest programme of fertiliser consumption will depend upon the extent to which the measures recommended by the Standing Committee on Manures and Fertilisers (*vide* para 5.1 above) are adopted by the Centre and the State Governments. A well organised extension service and properly trained village level workers for demonstrating the benefit of fertiliser use in crop production are the essential pre-requisites for the success of the programme. The provision of credit and of adequate supplies of fertilisers at reasonable prices is equally important.

21.3. The proper benefits of the use of chemical fertilisers cannot, however, be realised unless fertilisers are used in conjunction with bulky organic manures. It is accordingly necessary that intensive propaganda for the preparation of compost and other organic manures should be carried out simultaneously with the programme of popularising the use of chemical fertilisers.

Nitrogen and Phosphoric Acid Requirements 1960-61

Table I gives the estimated consumption of nitrogen (N) and phosphorus (P_2O_5) in the different States in 1960-61. The estimated distribution of nitrogen is further indicated in the map (Fig. I).

Nitrogen Materials

(1) *Ammonium sulphate*—Ammonium sulphate may be used for direct application to all crops and all types of soil except the acid soils when it should be used in combination with lime or bulky organic matter. It is to be preferred for use in the manufacture of mixed fertilisers because of its favourable effect upon the physical properties of mixed fertilisers.

(2) *Ammonium sulphate-nitrate*—Ammonium sulphate-nitrate may be used in all types of soil and for direct application to all crops, with the possible exception of paddy in the early stages of crop growth. This fertiliser may also be used in all parts of India for the manufacture of mixed fertilisers.

(3) *Urea*—Urea is suitable for application in all types of soil. It can be used for direct application to all crops with the possible exception of paddy and jute in areas of extremely high humidity. It cannot be used for the manufacture of mixed fertilisers except when relatively small quantities of it are required in preparing mixed fertilisers.

(4) *Ammonium nitrate fertiliser*—Ammonium nitrate fertiliser (20—26 per cent nitrogen) containing an inert diluent (but not limestone) is most suitable for drier regions, such as north-western India and the Deccan. This fertiliser is suitable for direct application to all crops, with the possible exception of paddy in the early stages of growth. (The results of experiments carried out during last year have shown that ammonium nitrate is as efficient as ammonium sulphate in its effect on paddy). It cannot be used in mixed fertilisers because of its adverse effect on physical properties when used in large quantities.

Phosphatic Fertilisers—Superphosphate is the most suitable form of phosphatic fertilisers for use throughout India, either for direct application or for use in mixed fertilisers except for lateritic soils, where it should be used in combination with bulky organic matter. It can be recommended for all areas in the country.

Mixed Fertilisers—It is estimated that two-thirds of phosphorus (P_2O_5) and double the quantity of nitrogen (N) will be marked in the form of mixed fertilisers in which the average ratio of N:P. is 2:1. This will, therefore, require about 80,000 tons P_2O_5 and 160,000 tons of nitrogen mostly in the form of ammonium sulphate and ammonium sulphate-nitrate. The balance of phosphate, *i.e.*, about 40,000 tons P_2O_5 will be used for direct application to crops, principally legumes in rotation.

Explanation of Fertiliser Map

Zone I

Zone I will comprise Jammu and Kashmir, Himachal Pradesh, the Punjab, PEPSU, Delhi, U.P. and north-western portion of Rajasthan commanded by the Bhakra-Nangal irrigation system.

When irrigation is fully developed, the important crops of this Zone will be wheat, cotton, paddy, sugarcane, oilseeds, chillies, potatoes, fruits, vegetables and forage legumes (berseem).

Both urea and ammonium nitrate fertiliser will be suitable for this Zone. It is recommended that the chief fertiliser of this Zone should be ammonium nitrate fertiliser, but if for technological reasons, ammonium nitrate fertiliser cannot be produced, urea should be the principal fertiliser.

Some quantities of ammonium sulphate and/or ammonium sulphate-nitrate will be required for making mixed fertilisers as both urea and ammonium nitrate fertiliser are not suitable for this purpose. If it is finally decided to produce ammonium nitrate fertiliser for this Zone, some quantities of ammonium sulphate will also be required for application to paddy crops in early stages of growth.

The quantities of ammonium nitrate fertiliser and ammonium sulphate-nitrate or ammonium sulphate required in this Zone are as under:—

		Tons
Ammonium nitrate fertiliser (20—26 per cent)	...	90,800
Ammonium sulphate or ammonium sulphate-nitrate	...	22,700
Total	...	1,13,500

Zone II

Zone II will comprise Rajasthan (exclusive of the north-western portion commanded by the Bhakra-Nangal irrigation system), Ajmer, Madhya Bharat, Vindhya Pradesh, Bhopal, Saurashtra, Kutch, Bombay and Hyderabad.

The important crops of this Zone are millets, cotton, wheat, paddy (mostly rainfed) sugarcane, oilseeds, fruits and vegetables.

Both ammonium sulphate-nitrate and urea will be equally useful for this Zone. Ammonium nitrate fertiliser can also be used under controlled irrigation in this Zone.

The quantities of ammonium sulphate-nitrate, urea and ammonium nitrate fertiliser required in this Zone are as under:—

		Tons
Ammonium sulphate-nitrate	...	50,000
Urea and ammonium nitrate fertiliser ...	...	25,600
Total	...	75,600

Zone III

Zone III comprises Mysore, Coorg, Travancore-Cochin, Madras, Andhra, Orissa, Bihar, W. Bengal, Assam, Tripura and Manipur.

The important crops of this Zone are paddy (mostly rainfed), jute, sugarcane, tobacco, cotton (mostly grown in the southern part of the Zone), potatoes, maize, tea, coffee and other plantation crops.

Ammonium sulphate-nitrate, ammonium sulphate and Urea will be useful in the different parts of this zone.

The quantities of ammonium sulphate-nitrate, ammonium sulphate and urea required in the Zone are as under:—

		Tons
Ammonium sulphate-nitrate	...	75,000
Ammonium sulphate	...	75,000
Urea	...	33,900
Total	...	1,83,900

Table 1

ESTIMATED CONSUMPTION OF N AND P_2O_5—1960-61.

Zone	State	Tons N	Tons N Total	Tons P_2O_5	Tons P_2O_5 Total
I	Punjab	50,000		6,500	
	Pepsu	12,000		2,000	
	H. P.	2,000		700	
	U.P.	44,000		10,000	
	Rajasthan (North-west)	2,000		500	
	Jammu & Kashmir	3,000		600	
	Delhi	500	113,500	100	20,400
II	Rajasthan except (North-west) ..	1,000		200	
	Ajmer	200		100	
	M. B.	6,000		1,000	
	V. P.	2,000		700	
	M.P.	22,000		6,000	
	Bhopal	3,000		500	
	Saurashtra	2,000		500	
	Kutch	400		100	
	Bombay	21,000		6,500	
	Hyderabad	18,000	75,600	9,000	24,600
III	Mysore	18,000		5,000	
	Coorg	500		200	
	Travancore-Cochin	12,000		9,500	
	Madras	40,000		15,000	
	Andhra	34,000		6,000	
	Orissa	15,000		5,000	
	Bihar	34,000		22,000	
	West Bengal	20,000		9,500	
	Assam	10,000		2,000	
	Tripura	200		150	
	Manipur	200	183,900	150	75,000
	Grand Total ..	373,000	373,000	120,000	120,000

ADDENDA

Note on "Nitrogen and Phosphoric Acid Requirements 1960-61"

Please *add* the following foot-note at the end of the Explanation of Fertiliser Map:—

"N.B.—The figures given above are expressed in terms of nitrogen (N)."

ANNEXURE V

STANDARD VACUUM REFINING COMPANY OF INDIA LTD.
CURRENT REFINERY GAS—COMPOSITION AND VOLUME

Quantity	Total Refinery Excess Gas 2300 MSCF/D		
Temp. °F	90		
Pressure Psig.	20		
Composition	Vol. %	MSCF/D	Lb-moles/D
CO_2	1·64	38	100
CO	1·15	26	69
H_2	0·89	20	53
O_2	0·23	5	13
N_2	9·66	222	586
CH_4	17·86	411	1,084
C_2H_4	7·09	163	430
C_2H_6	12·35	284	749
C_3H_6	15·60	359	948
C_3H_8	13·12	302	797
C_4H_8	6·46	149	393
C_4H_{10}	13·15	302	798
C_5	0·80	18	48
C_6	..	..	..
Total ..	100·00	2300	6065

ANNEXURE VI

STATEMENT I—COST OF PRODUCTION OF AMMONIA IN PLANTS OF DIFFERENT CAPACITIES

Nitrogen per year, Tons	Ammonia per year Tons	Cost per ton ammonia Rs.	Cost per ton nitrogen Rs.	Ratio
10,000	12,100	517	628	145
20,000	24,200	449	545	126
30,000	36,400	408	495	114
40,000	48,500	382	464	107
50,000	60,600	370	449	103
60,000	73,000	364	441	102
70,000	85,000	358	435	100
80,000	97,000	352	427	98·5
90,000	109,000	346	420	96·5
100,000	121,000	342	415	95·5

STATEMENT II—COST OF PRODUCTION OF AMMONIUM NITRATE IN PLANTS OF DIFFERENT CAPACITIES (AMMONIA FROM THE SAME SIZE PLANT).

Nitrogen per year, Tons	Nitrate per year, Tons	Cost per ton Nitrate Rs.	Cost per ton N Rs.	Ratio
10,000	28,500	355	1,012	157
20,000	57,000	300	856	133
30,000	85,500	270	770	119
40,000	114,000	249	710	110
50,000	143,000	236	675	105
60,000	172,000	229	655	102
70,000	200,000	226	645	100
100,000	285,000	224	640	99·5

STATEMENT III—COST OF PRODUCTION OF AMMONIUM SULPHATE BY GYPSUM PROCESS IN PLANTS OF DIFFERENT CAPACITIES (AMMONIA FROM THE SAME SIZE PLANT)

Nitrogen per year, Tons	Sulphate per year, Tons	Cost per ton, Sulphate Rs.	Cost per ton N. Rs.	Ratio
10,000	47,500	293	1,390	138
20,000	95,000	253	1,210	119
30,000	142,500	231	1,100	108·5
40,000	190,000	223	1,060	105·0
50,000	237,500	218	1,035	103·0
60,000	285,000	214·5	1,020	101·0
70,000	333,000	212·2	1,010	100·0
100,000	477,000	211·0	1,005	99·5

STATEMENT IV—COST OF PRODUCTION OF SULPHATE-NITRATE IN PLANTS OF DIFFERENT CAPACITIES USING GYPSUM PROCESS FOR SULPHATE

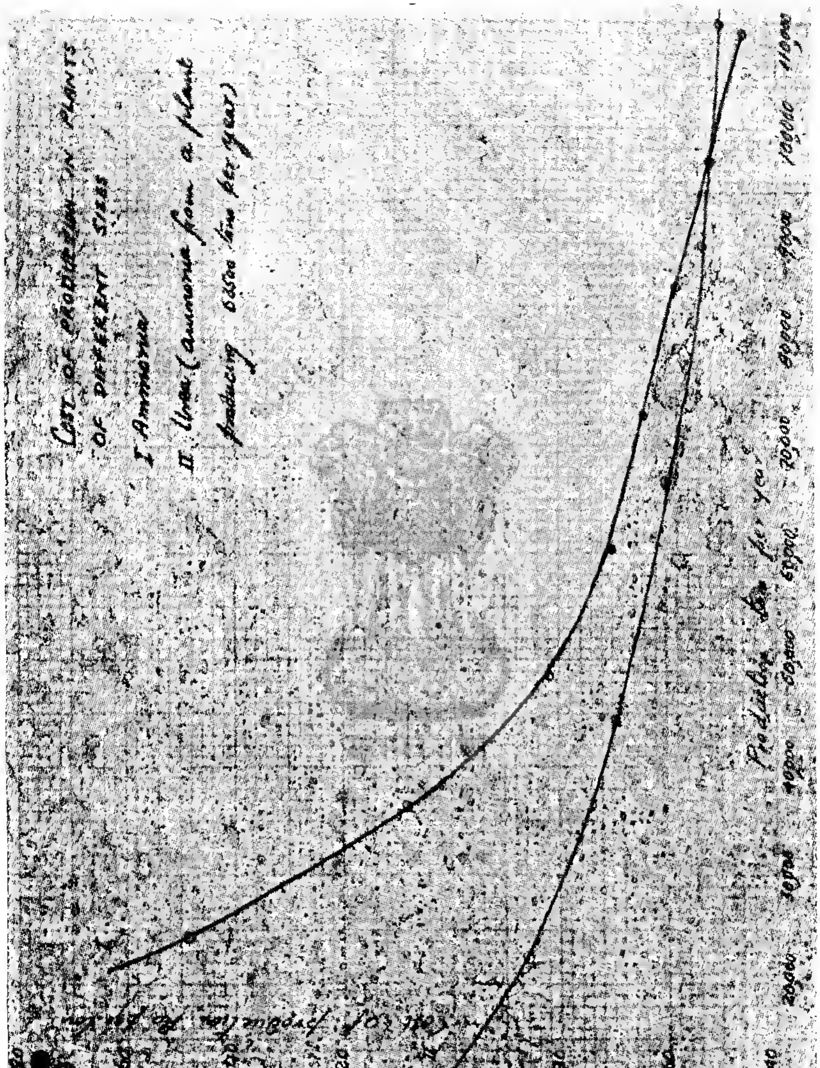
(1) Ammonia from same size plant.

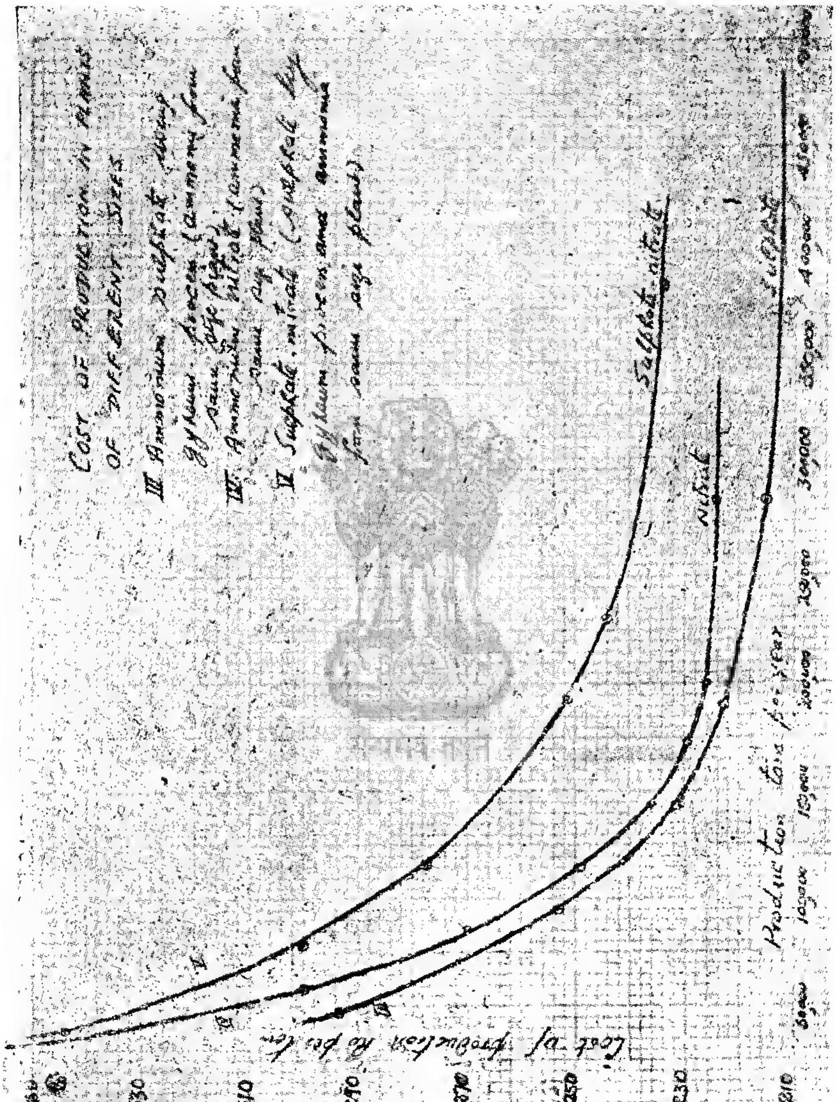
(2) Ammonia from 90,000 tons/year plant.

Nitrogen per year, Tons	Sulphate-nitrate per year, Tons	1			2		
		Cost per ton Rs.	Cost per Ton N Rs.	Ratio	Cost per ton Rs.	Cost per ton N Rs.	Ratio
10,000	38,500	344	1,325	143	290	1,115	124
20,000	77,000	300	1,150	125	272	1,045	114
30,000	115,000	277	1,065	115	260	1,000	109
40,000	154,000	261	1,005	108·5	250	960	105
50,000	192,500	251	965	104·5	244	940	102
60,000	231,000	244	940	101·5	240	920	101
70,000	269,500	240	920	100	238	915	100
100,000	385,000	233·5	900	97·5	233·5	900	98·0

STATEMENT V—COST OF PRODUCTION OF UREA IN PLANTS OF DIFFERENT CAPACITIES (AMMONIA FROM A PLANT PRODUCING 63,500 TONS OF AMMONIA/YEAR)

Nitrogen per year, tons	Urea per year, tons	Cost per ton Urea, Rs.	Cost per ton N. Rs.	Ratio
5,000	11,100	402	895	100
10,000	22,200	386	860	96
20,000	44,400	369·5	820	92
30,000	66,600	360·0	805	90
40,000	88,800	353·5	785	88
50,000	111,000	350·0	780	87
60,000	133,200	..	..	..
70,000	155,400	..	..	.


I Ammonia
Production ton per year


Cost of production in plants of different sizes
Sulphate nitrate
Nitrate
Sulphate
Production tons per year
Cost of production Rs per ton
210
230
250
270
290
310
330

ANNEXURE VII

Average Distribution Distance in Miles per ton of Fertilizer, and Freight Rates in Rupees per ton of Fertilizers

Location	100,000 Tons Nitrogen Single Unit Scheme		55,000 Tons Nitrogen Two Unit Scheme A.I.		45,000 Tons Nitrogen Two Unit Scheme A. II		50,000 Tons Nitrogen Two Unit Scheme A. II		33,000 Tons Nitrogen Three Unit Scheme	
	Distance in Miles	Freight in Rupees	Distance in Miles	Freight in Rupees	Distance in Miles	Freight in Rupees	Distance in Miles	Freight in Rupees	Distance in Miles	Freight in Rupees
1. Neyveli	587	25·0	290	14·9	267	13·9	241	12·8	176	10·1
2. Vijayawada	444	20·8	257	13·5	236	12·6	208	11·5	118	7·5
3. Durgapur	1,059	38·2	845	32·2	815	31·3	793	30·7	737	29·2
4. Hathras	1,023	37·1	716	28·6	688	27·8	651	26·8	550	23·9
5. Hanumangarh	1,299	44·9	987	36·1	952	35·1	910	34·0	786	30·5
6. Sawai Madhopur	988	36·1	685	27·8	654	26·8	6,915	25·8	501	22·5
7. Itarsi	670	27·3	402	19·7	383	18·8	358	17·7	288	14·9
8. Kothagudium	479	21·9	314	16·0	287	14·8	254	13·4	173	10·1
9. Ramagundam	476	21·8	310	15·8	284	14·7	254	13·4	198	11·0
10. Bombay	660	27·0	484	22·0	469	21·5	432	20·6	376	18·5
11. Sikka	1,014	36·8	804	31·1	770	30·1	727	28·8	625	26·1
Average freight		30·6		23·4		22·5		21·4		

Average Distribution (1) Vijayawada, Rajahmundry, Trichy and Mysore for Zone III B—55,000 Tons Nitrogen.
(2) Hyderabad, Baroda, Poona, Nagpur, Jubbalpur, Gwalior, Ujjain, Bhopal, Rajkot, Satna and Jodhpur, for Zone II—45,000 Tons Nitrogen.

See attached explanation for manner of calculation of "distance in Miles".

ANNEXURE VII—contd.

Explanation

For each of 15 distribution centres, the quantity of nitrogen to be distributed has been assumed to be as follows:

	Ton/N
1. Vijayawada	10,500
2. Rajahmundry	10,500
3. Trichinopoly	24,000
4. Mysore	10,000
5. Hyderabad	10,700
6. Nagpur	6,500
7. Jubbulpore	6,500
8. Poona	6,300
9. Baroda	6,300
10. Ujjain	1,800
11. Gwalior	1,800
12. Rajkot	1,400
13. Bhopal	1,800
14. Satna (V. P.)	1,200
15. Jodhpur	700
Total ...	100,000

Taking into account the distance in miles between each distribution centre and each selected location, the average distribution distance in miles per ton of fertilizer for each location has then been calculated by dividing the total ton-miles by the total quantity on nitrogen to be distributed. For quantities less than the total 100,000 tons, the required total tonnage distributed from a location is made up by starting from the nearest distribution centre and its requirements, then the next nearer distribution centre with its requirements, and so on till the total quantity under consideration (33000, 45000 and 55000 tons depending on the size of the factory) is reached.

ANNEXURE VIII

STATEMENT I

Assumed Costs of Raw Materials and Utilities

Location	Lignite or Coal Rs./Ton	Gypsum Rs./Ton	Medium pressure steam Rs./Ton	Low pressure steam Rs./Ton	By-product power pies/Kwh	Purchased power pies/Kwh	Raw water Rs./1000 galls	Treated water Rs./1,000 cft.	Refinery gas Rs./1,000 cft.
1. Neyveli*	6·6 (54% H_2O)	35 (85%)	2·0	1·81	6·25	6·25	0·3	0·374	
2. Vijayawada	29·0	46·5 (87%)	8·8	7·5	5·6	6·0	0·125	0·75	
3. Durgapur	17·0	45·0 (87%)	6·5	5·5	4·15	7·2	0·125	0·75	
4. Hathras	30·0	25·2 (87%)	8·0	7·0	4·85	9·0	0·50	1·0	
5. Hanumangarh	23·3 (26·7% H_2O)	14·7 (87%)	9·0	7·5	5·37	7·44	0·30	1·0	
6. Sawai Madhopur	28·2	24·0 (87%)	8·5	7·5	5·0	9·4	0·50	1·0	
7. Itarsi	20·0	32·4 (87%)	7·0	6·0	5·0	8·3	0·40	1·0	
8. Kothagudium	23·6	44·0 (87%)	8·0	7·0	4·85	8·9	0·15	0·8	
9. Ramagundam	25·0	41·7 (87%)	8·2	7·0	5·1	9·0	0·20	1·0	
10. Bombay	29·0	35·0 (97%)	8·3	7·0	5·9	6·6	1·0	1·5	3·04
11. Sikka	33·0	16·0	9·7	8·0	6·4	10·4	0·5	1·0	

*The assumed costs of raw materials and utilities for Neyveli have been taken from Powell-Duffryn report without any modification. Steam costs, it will be noticed, are remarkably low the reason for which probably is that the costing has been done on the basis of cost of fuel only without taking into account capital and other charges which have presumably been entirely debited to power.

STATEMENT II

Total Cost Rupees Per Ton Delivered Nitrogen

Location	Single Unit 100,000 T N_2		A—Two Unit Scheme 55,000 T N_2 45,000 T N_2						B—Two Unit Scheme 50,000 T N_2 50,000 T N_2					
	Urea and Double Salt	Urea and Sul-phate	Urea and Double Salt A-I	Urea and Double Salt A-II	Total A Urea and Double Salt	Urea and Sul-phate A-I	Urea and Sul-phate A-II	Total A Urea and Sul-phate	Urea and Double Salt B-I	Double Salt B-II	Total B Urea and Double Salt	Urea and Sul-phate B-II	Sul-phate B-III	Total B Urea and Sul-phate
1. Neyveli ..	856	972	900	948	921	995	1,060	1,023	884	944	914	936	1,094	1,015
2. Vijayawada ..	930	1,060	995	1,074	1,031	1,095	1,171	1,129	987	1,045	1,016	1,048	1,202	1,125
3. Durgapur ..	966	1,082	1,030	1,078	1,051	1,080	1,202	1,135	1,000	1,078	1,039	1,064	1,240	1,152
4. Hathras ..	952	1,039	1,021	1,072	1,044	1,077	1,140	1,105	1,025	1,050	1,040	1,052	1,140	1,095
5. Hanumangarh	949	1,003	1,014	1,058	1,034	1,040	1,090	1,064	1,018	1,034	1,026	1,038	1,086	1,061
6. Sawai Madhopur	945	1,046	994	1,085	1,035	1,019	1,150	1,133	1,032	1,065	1,048	1,061	1,141	1,100
7. Itarsi ..	920	1,009	987	1,039	1,011	1,047	1,111	1,076	983	1,021	1,003	1,024	1,120	1,072
8. Kothagudium	953	1,073	1,026	1,074	1,047	1,113	1,182	1,144	1,010	1,070	1,040	1,065	1,215	1,140
9. Ramagundam	953	1,065	1,021	1,072	1,047	1,107	1,178	1,139	1,018	1,067	1,043	1,071	1,204	1,137
10. Bombay ..	864	945	902	935	916	962	999	979	887	937	912	923	1,030	976
11. Sikka ..	976	1,008	1,050	1,092	1,068	1,071	1,119	1,093	1,038	1,068	1,063	1,070	1,110	1,090

STATEMENT III 130,000 tons Ammonia

Single Unit Plan 65,000 tons Urea (45%N)

275,000 tons Double salt or 340,000 tons Sulphate

Location	Ammonia (130,000 tons)		Freight per ton ferti-liser	Urea (65,000 tons) (29,000 tons N)			Double Salt (275,000 tons) (71,000 tons N)			Sulphate (340,000 tons) (71,000 tons N)		
	Cost per ton	Cost per ton N		Cost per ton	Cost per ton includ-ing freight	Total cost per ton N	Cost per ton	Cost per ton includ-ing freight	Total cost per ton N	Cost per ton	Cost per ton includ-ing freight	Total cost per ton N
1. Neyveli	289·4	351	25·0	305·56	330·56	735	207·6	232·6	905	199·3	224·3	1,070
2. Vijayawada	326·2	396	20·8	335·43	356·23	792	236·56	257·36	987	225	245·8	1,170
3. Durgapur	304·4	369	38·2	319·7	357·9	796	226·1	264·9	1,020	214·1	252·3	1,200
4. Hathras	344·8	419	37·1	349·1	386·2	857	220·5	257·6	989	196·8	233·9	1,115
5. Hanumangarh	339·5	412	44·9	344·9	389·8	866	211	255·9	984	177·7	222·6	1,060
6. Sawai Madhopur	358·6	435	36·1	358·8	394·9	878	227	263·1	972	197·6	233·7	1,112
7. Itarsi	329·4	400	27·3	337·1	364·4	810	224·1	251·4	965	201·6	228·9	1,090
8. Kothagudium	344·6	348	21·9	348	369·9	821	240·1	262	1,007	225·3	247·2	1,176
9. Ramagundam	348·7	424	21·8	351	372·8	829	239·6	261·4	1 004	222·5	244·3	1,162
10. Bombay	277·3	336	27·0	308·1	335·1	745	209·7	236·7	912	188·4	215·4	1,025
11. Sikka	376·8	458	36·1	370·8	407·6	906	225	261·8	1,006	184·5	221·3	1,051

STATEMENT IV — 72,000 tons Ammonia

Two Unit Plan A — 44,000 tons Urea

Unit I — 138,000 tons Double salt or 170,000 tons Sulphate

Location	Ammonia (72,000 tons)		Freight per ton fertiliser	Urea (44,000 tons) (19,000 tons N)			Double Salt (138,000 tons) (36,000 tons N)			Sulphate (179, 000 tons) 36,000 tons N		
	Cost per ton	Cost per ton N		Cost per ton	Cost per ton including freight	Total cost per ton N	Cost per ton	Cost per ton including freight	Total cost per ton N	Cost per ton	Cost per ton including freight	Total cost per ton N
1. Neyveli ..	332·7	404	14·9	342·5	357·4	795	233·5	248·4	956	215·7	230·6	1090
2. Vijayawada	369·3	448	13·5	372·6	386·1	859	264	277·5	1065	242·4	255·9	1220
3. Durgapur ..	347·7	422	32·2	356·5	388·7	865	253·9	286·1	1060	231·3	263·5	1252
4. Hathras ..	388·3	471	28·6	386·3	414·9	924	250·3	278·9	1072	214	242·6	1154
5. Hanumangarh	383·0	465	36·1	382·1	418·2	930	239·3	275·4	1060	195·5	231·6	1101
6. Sawai Madhopur	402·5	490	27·8	395·4	423·2	940	255·2	283·0	1090	215·3	243·1	1156
7. Itarsi ..	372·9	453	19·7	374·4	394·1	876	252·9	272·6	1050	219·3	239	1139
8. Kothagudium	389·9	474	16·0	386·3	402·3	895	269·1	285·1	1097	243·1	259·1	1232
9. Ramagundam	392·2	476	15·8	388·3	404·1	897	267·8	283·6	1090	240·1	255·9	1219
10. Bombay ..	293·7	357	22·0	328·8	350·8	795	228·5	250·5	960	198·5	220·5	1050
11. Sikka ..	420·3	510	31·1	408	439·1	975	252·9	284·0	1091	205·3	236·4	1125

STATEMENT V — 58,000 tons Ammonia

Two Unit Plan A — 21,000 tons Urea

Unit II — 138,000 tons Double Salt or 170,000 tons Sulphate

Location	Ammonia (58,000 tons)		Freight per ton fertiliser.	Urea (21,000 tons) (9,000 tons N)			Double Salt (138,000 tons) (36,000 tons N)			Sulphate (170,000 tons) (36,000 tons N)		
	Cost per ton	Cost per ton N		Cost per ton	Cost per ton including freight	Total cost per ton N	Cost per ton	Cost per ton including freight	Total cost per ton N	Cost per ton	Cost per ton including freight	Total Cost per ton N
1. Neyveli ..	352·0	427	12·8	372·6	385·4	855	239·7	252·5	971	220·7	233·5	1110
2. Vijayawada	388·6	472	11·5	402·4	413·9	920	271·2	282·7	1087	247·9	259·4	1232
3. Durgapur ..	367	445	30·7	386·0	416·7	926	260·4	291·1	1120	236·8	267·5	1272
4. Hathras ..	407·4	495	26·8	415·8	442·6	984	258·9	285·7	1100	219·5	246·3	1175
5. Hanumangarh	402·3	489	34·0	411·6	445·6	991	245·6	279·6	1074	200·5	234·5	1118
6. Sawai Madhopur	421·6	513	25·8	425	450·8	1015	261·9	287·7	1105	220·7	248·5	1175
7. Itarsi ..	392	476	17·7	403·8	421·5	938	258·9	276·6	1052	224·9	242·6	1157
8. Kothagudium	407·2	495	13·4	414·6	428·0	931	275·9	289·3	1110	247·8	261·2	1240
9. Ramagundam	411·3	500	13·4	417·7	431·1	959	274·3	287·7	1105	245·2	258·6	1231
10. Bombay ..	302	366	20·6	340·2	260·8	803	231·5	252·1	970	201	221·6	1050
11. Sikka ..	439·4	534	28·8	437·5	466·3	1038	258·9	287·7	1105	210·8	239·6	1140

STATEMENT VI 65,000 tons Ammonia
Two Unit Plan B 65,000 tons Urea (Partial Recycle Process)
Unit I 80,000 tons Double Salt, or 98,000 tons Sulphate

Location	Ammonia (65,000 tons)		Freight per ton fertiliser	Urea (65,000 tons) (29,000 tons N)			Double Salt (80,000 tons) (21,000 tons N)			Sulphate (98,000 tons) (21,000 tons N)		
	Cost per ton	Cost per ton N		Cost per ton	Cost per ton and freight	Total cost per ton N	Cost per ton	Cost per ton and freight	Total cost per ton N	Cost per ton	Cost per ton and freight	Total Cost per ton N
1. Neyveli ..	341·2	415	13·9	345·1	359·0	797	247·4	261·3	1004	223·6	237·5	1130
2. Vijayawada	378·0	460	12·6	378·0	390·6	868	285·8	298·4	1150	259·5	272·1	1295
3. Durgapur ..	356·2	432	31·3	360·5	391·8	872	275·4	306·7	1180	248·5	279·8	1330
4. Hathras ..	396·7	482	27·8	388	415·8	925	273·0	300·8	1155	231·3	259·1	1235
5. Hanumangarh	391·4	475	35·1	385·3	420·4	935	260·5	295·6	1137	212·2	247·3	1178
6. Sawai Madhopur	410·9	500	26·8	397·4	424·2	940	276·9	303·7	1165	232·3	259·1	1235
7. Itarsi ..	381·3	483	18·8	380·3	399·1	886	273·6	292·4	1121	236·1	254·9	1214
8. Kothagudium	396·5	482	14·8	388·7	403·5	896	290·0	304·8	1172	259·6	274·4	1305
9. Ramagundam	400·6	486	14·7	395·6	410·3	912	289·6	304·3	1170	257·4	272·1	1297
10. Bombay ..	297·4	362	21·5	332	353·5	785	248·7	270·2	1040	214·4	235·9	1122
11. Sikka ..	428·7	520	30·1	409·5	439·5	977	274·1	304·2	1170	222·5	252·6	1202

STATEMENT VII — *Two Unit Plan B* — *Unit II*

65,000 tons Ammonia
195,000 tons Double Salt or 240,000 tons Sulphate

Location	(65,000 Tons Ammonia)		Freight per ton fertilizer	195,000 Tons Double Salt (50,000 tons N_2)			240,000 Tons Sulphate (50,000 tons N_2)		
	Cost per ton	Cost per ton N_2		Cost per ton	Cost and freight	Total cost per ton N_2	Cost per ton	Cost and freight	Total cost per ton N_2
1. Neyveli	341·2	415	13·9	231·5	245·4	944	215·7	229·6	1093
2. Vijayawada ..	378·0	460	12·6	259·3	271·9	1045	240·4	253·0	1202
3. Durgapur	356·2	432	31·3	248·8	280·1	1078	229·3	260·6	1240
4. Hathras	396·7	482	27·8	246·4	274·2	1055	212·1	239·9	1140
5. Hanumangarh ..	391·4	475	35·1	233·9	269·0	1034	193	228·1	1086
6. Sawai Madhopur ..	410·9	500	26·8	250·3	277·1	1065	213	239·8	1140
7. Itarsi	381·3	463	18·8	247	265·8	1021	216·8	235·6	1120
8. Kothagudium ..	396·5	482	14·8	263·4	278·2	1070	240·3	255·1	1215
9. Ramagundam ..	400·6	486	[illegible]	[illegible]	[illegible]	1068	238·2	252·9	1205
10. Bombay	297·4	360	21·5	222·2	243·7	937	195·2	216·7	1030
11. Sikka	428·7	520	30·1	247·5	277·6	1068	203·3	233·4	1110

ANNEXURE IX

Statement of New Transportation Involved on the Basis of 100,000 Tons (Nitrogen) Per Year Factory Producing 340,000 Tons of End Products Annually

Location	Coal for gasification ton/day	Coal for steam and power ton/day	Total coal ton/day	Distance miles	Ton-miles for coal per day	Gypsum tons/day	Distance miles	Ton-miles for gypsum per day	Total ton-miles for raw materials per day	Average distance for raw material	Ton miles for distribution per day	Total ton-miles per day
1. Neyveli ..	..	..	..	..	..	840	45	37,800	37,800	45	587×1000 =587,000	6,24,800
2. Bombay	..	150	150	500	75,000	740	579	4,28,000	5,03,000	565	660×1000 =660,000	11,63,000
3. Itarsi ..	720	885	1,605	50	80,250	840	695	5,83,000	6,63,250	270	670×1000 =670,000	13,33,250
4. Vijayawada	740	290	1,030	111	1,14,000	840	1,290	10,80,000	11,94,000	640	444×1000 =444,000	16,38,000

ANNEXURE X

Reports of the Sindri Technological Department on (a) Safe Limit of Nitrogen Content in Diluted Ammonium Nitrate and (b) Selection of Suitable Non-alkaline Diluents for Ammonium Nitrate.

SINDRI FERTILIZERS AND CHEMICALS LTD.

TECHNOLOGICAL DEPARTMENT

Sindri, the 29th April 1955

SUBJECT:—*Safe Limit of Ammonium Nitrate content in fertilizer mixtures*

It is very difficult to fix absolute figures for safe maximum limits of ammonium nitrate content in fertilizer mixtures from available data in literature. Even in countries where these fertilizers are largely used only meagre data is available.

In Germany, in mixtures of ammonium nitrate with inert diluents, employment of ammonium nitrate beyond 60 per cent in any mixture is forbidden by law (1). During discussions with manufacturing firms of double salt, the undersigned was given to understand that so long as the nitrogen content did not exceed 28 per cent, the material was safe i.e. in this case the ammonium nitrate content cannot go beyond 48.5 per cent. With a margin for safety, the nitrogen content of double salt has been fixed by the German Government at 26 per cent. (2) In this case the ammonium nitrate content is 34.8 per cent.

The Underwriters Laboratories Inc. of America have found that ammonium nitrate mixed with ammonium sulphate in equimolecular proportions and ammonium nitrate mixed with 80 to 100 mesh pulverised limestone in the proportion of 60 to 35 are entirely non-hazardous (3). Following World War I, ammonium nitrate was mixed with gypsum to the extent of 60 per cent and excellent results were reported from the use of this mixture (3).

Another author reports that subsequent to the Texas disaster in 1947, efforts were made towards a requirement that ammonium nitrate be mixed with other non-explosive material to the equivalent of 75 per cent of its original concentration on the theory that cal-nitro (essentially a mixture of ammonium nitrate and calcium carbonate) of that content has not been known to explode. The author contends, however, that the validity of this presumption is dubious, since a sufficiently high temperature could cause the ammonium nitrate to melt out of the mixture and collect as a pool of the virtually pure salt. (4).

From the available data, therefore, it is difficult to fix the absolute safe limits for ammonium nitrate content in fertilizer mixtures. The question is further complicated by the fact that there are many factors which influence the behaviour of ammonium nitrate such as:

1. The impurities present; particularly chlorides, nitrites and carbonaceous matter which act as sensitisers.

It has been mentioned in literature that one intriguing fact that may or not be significant is that large quantities of ammonium nitrate have been known to burn under various conditions but explosions of major consequence following initial burning have occurred only in a marine environment (4). Winnacker and Weingaertner report that quick heating of ammonium nitrate over 260°C leads to an explosive decomposition which is accelerated by chloride ions (5).

Cook has reported from investigations after the Texas explosion that in comparison with inorganic coated—e.g. Kieselguhr—or pure ammonium nitrate, ammonium nitrate—wax compositions (the waxes being applied as coating material to the extent of 1 per cent to reduce hygroscopicity and caking tendencies) are tremendously more sensitive and likely to explode under provocative conditions as when large quantities are involved in a fire. These waxes, because of their fuel value, act as sensitisers, gradually increasing in sensitisation till zero oxygen balance is reached, though, because of their lubricating properties, they act as desensitisers when incorporated in large doses. Cook has found that nitrate-hydrocarbon mixtures thus pass through maximum sensitiveness experimentally at somewhere between .75 and 1.5 per cent, though this is also unfortunately the desirable wax content required for satisfactory moisture resistance, antisetting and free flowing properties of ammonium nitrate. (6).

Cook also found that the thermal stability of nitrate hydrocarbon mixtures is lowered phenomenally in the presence of carbonaceous matter. He determined that while the explosion temperature of nitrate-hydrocarbon mixtures is in the range of 270° to 350°C, the explosion temperature is lowered to around 150°C in the presence of bagging paper or cellulose with decomposition taking place at an appreciable rate as low as 100°C. (6). Kirk and Othmer point out that while the admixture of up to 8 per cent of carbonaceous material sensitises ammonium nitrate, such mixtures also decrease in sensitivity with increase in density (7).

2. The grain structure and fineness of the ingredients employed in ammonium nitrate fertilizer mixtures. It has been found that production of large crystals or granules has aided somewhat in the production of a better physical condition for pure nitrate fertilizers. (3) In admixture with inert diluents the proper size distribution has to be obtained. The possibility exists that the ammonium nitrate can creep out and segregate as the pure salt which is undesirable.

3. The ambient temperature which is an important factor in view of the fact that the normal temperatures prevailing in the country during a major part of the year is over 32.5°C when the L. form of nitrate exists which is more susceptible to explosion than the B allotrope.

From the foregoing it is clear that it is reasonable to surmise that in admixtures with chalk, gypsum or Kaolin, the safe maximum limit for ammonium nitrate content in the mixture may only be 60 per cent and this figure may be provisionally recommended till extensive experiments have been carried out with various diluents in the climatic and other conditions of the country and the results so obtained have been statistically analysed.

(Sd.)

Chief Technologist

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SINDRI FERTILIZERS AND CHEMICALS LTD.

TECHNOLOGICAL DEPARTMENT

Study on the possibility of employing various diluents instead of chalk in ammonium nitrate fertilizers

Object—The investigations have been carried out to determine the suitability of a few diluents for blending with ammonium nitrate fertilizer to improve its keeping quality and also reduce explosive hazards.

The diluents that have been employed are (1) gypsum (2) Damodar river clay (3) infusorial earth from Burma (4) Grey and white kaolin samples from Neyveli. Investigations will be continued on samples of clay from Nangal and Neyveli when they arrive.

The tests have been conducted to assess the suitability of these materials on the basis of (1) Hygroscopicity (2) caking tendency (3) PH of water extract and (4) bulk density.

1. *Procedure*—A saturated solution of ammonium nitrate is evaporated on a water bath until the solution reaches such a consistency that it will solidify immediately on cooling.

Meanwhile the diluent, dried to constant weight at 60°C is ground to —100, + 120 mesh size distribution. To the nitrate melt, the calculated amount of the diluent is added so that it will form 40 per cent of the final mixture. The resulting mass is cooled and stirred to form granules, crushed, if necessary, and screened to —10, + 22 mesh size distribution.

The product is utilised for investigations on hygroscopicity and caking tendency.

2. *Hygroscopicity*—Approximately 1 gm. of each, dried to constant weight at 60°C is weighed accurately in a petridish and exposed to a humidity of 81 per cent (over saturated ammonium sulphate) for a period of eight days. Ambient temperatures during the tests have also been noted.

In two batches of experiments. (a) weights were measured every day and increases for every 24 hour period were calculated. The percentage increase in weight is calculated both on the weight of the samples as such and on the ammonium nitrate content. (b) In the other batch, weights are taken every four hours four times a day. The percentage increase is calculated on 4 hourly basis (with temperature conditions prevailing at the time) and also on the day to day readings.

3. *Caking Tendency*—(a) Equal weights of each sample were filled in 4″×6″ cotton twill bags and the bags were sealed by tying with thread. Each bag was subjected to a constant load at a constant humidity of 100 per cent for 8 days. Every day the bag was taken out and dried at 60°C for three hours in order to simulate alternate hot, and dry and cold humid conditions.

At the end of the eight day period, the bag was dropped on to a concrete floor four times from a height of 3′ and then a size analysis was carried out on the material in the bag.

The samples were then loosened, filled in the bags again and the experiment was repeated for one week.

(b) In another batch of experiments, equal quantities of each sample were filled in four bags each and the four bags of each material were kept stacked one over another with a constant load on top at a constant humidity of 100 per cent. Every third day, the bottommost bag was taken out, dried at 60°C for 3 hours and the sieve analysis carried out. In these experiments after removal of each bag, dummy bags in lieu were not introduced in the stack. These experiments will be repeated employing this procedure when more material is available.

(a) Bulk density determinations were also carried out on the various diluents (Lbs/Cu. Ft.). The samples in ascending order of bulk density are grey kaolin (Neyveli), Infusorial earth (Burma), White Kaolin, Chalk, Gypsum and river clay.

(b) The PH values of water extracts of the diluents were measured and the materials in ascending order of PH are of grey kaolin, River Clay, Gypsum, Chalk, White Kaolin and industrial earth.

Results—The results of the hygroscopicity tests are shown in Tables I to V. The results can be judged from the summary presented in Tables III and page 3 of Table V. The other tables show details of the experiments only. It may also be mentioned that the results are only comparative amongst various materials and should not be taken as absolute figures for each material.

It is observed that the percentage increase in moisture absorption is more or less proportional to the ammonium nitrate content in the case of mixtures with gypsum, river clay and chalk; these diluents neither increase nor decrease the moisture absorption capacity of ammonium nitrate. But with mixtures having infusorial earth, grey and white kaolin as diluents, the increase in weight is more than what would be attributable to ammonium nitrate. In order to assess whether the increased hygroscopicity is due to the admixture of nitrate with diluent or the diluent alone, samples of these diluents were exposed to controlled humidities and as is shown in Table I, there is very little increase in weight in the case of gypsum and kaolin samples whereas appreciable increase in weight occurs in the case of infusorial earth.

Results of caking studies are shown in Tables VI and VII. It is observed that in the kaolin samples the cake does not yield much of powder below—22, mesh size. The percentage in the—10, + 22 range is quite high showing thereby that the original granules do not either lump together or fall to powder, though the moisture absorption is higher in these cases. The others in the decreasing order of efficiency are river clay, gypsum and chalk, and infusorial earth. In the case of river clay, gypsum and to some extent grey kaolin, it has been observed that there is a tendency towards segregation and for ammonium nitrate to creep out of the bag. The caking is least in the case of white Kaolin in these series of experiments. As expected, the caking increases with time of storage.

Discussion—A survey of literature on conditioning agents for ammonium nitrate indicates that the results of small scale short term laboratory tests are not conclusive and sometimes are not confirmed by long term plant scale tests. The results obtained have to be viewed in this perspective.

It has also been observed in literature that for the improvement of the keeping quality of ammonium nitrate two pretreatments may be necessary: (i) water repellant coating and (ii) dusting material.

Neither of these two by itself alone is conducive to improvement of keeping quality. In the T.V.A., for example, a mixture of rosin, petrolatum and paraffin has been employed as water repellant coating material and kaolin, kieselguhr, plaster of paris and soap-stone as dusting materials. They have also found that a low bulk density and a high oil absorbivity are indicative of the usefulness of a material as a good dusting medium; and the material and manufacture of bags also play an important part in the storage of conditioned ammonium nitrate in bulk. ('Production of grained ammonium nitrate fertiliser' by Miller, Lenaeus, Seamen and Dokken, Ind. Eng. Chem., 38, 709, 1946).

These observations are confirmed to some extent by the present series of experiments though it may be noted that we did not use any dusting materials as such. The diluents alone in admixtures with nitrate have not proved to be completely satisfactory. Low bulk density kaolin is effective in minimising caking though the moisture absorption increases. Though the series of experiments are far from complete and further investigations have to be carried out after receipt of material from Neyveli and Nangal, the present results indicate that gypsum is better than chalk as diluent in respect of hygroscopicity, though gypsum is not so good as chalk in respect of caking tendency; but here also it is very near the quality of chalk. The alkalinity is also favourable from the viewpoint of any loss of ammonia during storage. These observations indicate that chalk can be substituted by gypsum at Nangal.

Subsequent to World War I, Germany mixed nitrate with gypsum, the latter to the extent of 60 per cent and they reported excellent results of the use of this material. Besides reducing explosion hazards, gypsum will exert beneficial effects on the soil as in the case of superphosphate which is said to owe a part of its fertilizer value to the presence of gypsum. ('Commercial Fertilizers' by Collings).

In view of the Kaolins from Neyveli contributing towards least caking tendency, experiments will also be continued with samples of these materials from Neyveli and Nangal in bulk when they arrive. At present experiments are in progress on (1) use of plaster of paris with gypsum as diluent (2) gradual substitution of ammonium sulphate in the double salt by gypsum (3) Employment of dusting materials.

Technological Department
Sindri Fertilizers and Chemicals Ltd.

TABLE I

Hygroscopicity Test on Diluent Materials

1	2	3	4							
Diluent	Granule size	Initial Wt. gms.	Moisture absorption at 81% R.H. Daily increase in Wt. in gms.							
			1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Infusorial Earth ..	—10 +22 mesh	0·9358	0·1140	0·0180	0·0072	0·0032	—0·0284	0·0164	—0·0016	0·0058
Gypsum	Do.	1·0218	0·0050	..	0·0012	—0·0006	..	—0·0004	0·00	0·0002
Gray Kaolin	Do.	1·007	0·0158	..	—0·0004	0·0002	..	—0·0004	—0·0006	0·0002
White Kaolin	Do.	1·0038	0·0126	..	—0·0008	0·0004	..	0·0012	—0·0006	0·0002

5								6
% moisture absorption								Cumulative % moisture absorbed over 8 days
1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day	
12·18	1·92	0·77	0·342	..	1·75	..	0·62	17·582
0·49	..	0·117	..	..	..	..	..	0·607
1·58	..	..	0·0198	..	..	..	0·0198	1·62
1·26	..	..	0·0398	..	0·1195	..	0·8756	2·295

TABLE II

Hygroscopicity Test on Ammonium Nitrate with Diluent Materials

(a) Pure NH_4 NO_3

(b) 60% NH_4 NO_3 + 40% diluent material

(a) On Pure NH_4 NO_3

Wt. of sample taken=0.9840 gms......1st Set.

Wt. of sample taken=0.9754 gms......2nd Set.

Days	Increase Wt. gms.		% increase in Wt. on the basis of mixture	
	1st Set	2nd Set	1st Set	2nd Set
1st	0.08	0.0874	8.14	8.95
2nd	..	0.1352	..	13.85
3rd	0.317	0.0886	32.2	9.1
4th	0.1098	0.1700	11.17	17.4
5th	0.0106	0.1644	11.21	16.85
6th	0.1006	..	10.2	..
7th	0.0696	0.1286	7.075	13.2
8th	0.0638	0.0434	6.08	4.4
Cumulative ..	0.8514	0.8176	86.5	83.75

(b) 1. 60% NH_4 NO_3 + 40% Clay.

Wt. of sample taken=0.9780 gms.......1st Set.

Wt. of sample taken=0.9860 gms.......2nd Set.

Days	Increase Wt. gms.		% increase in Wt. on the basis of mixture		% increase in Wt. on the basis of nitrate alone	
	1st Set	2nd Set	1st Set	2nd Set	1st Set	2nd Set
1st	0.0782	0.1278	8.00	12.95	13.3	2.55
2nd	..	0.1372	..	13.9	..	23.16
3rd	0.2422	0.0686	24.75	6.95	41.25	16.55
4th	0.0564	0.0780	5.75	7.9	9.6	13.16
5th	0.0380	0.0334	3.88	3.4	6.46	5.66
6th	0.0612	..	6.25	..	10.4	..
7th	0.0280	0.0320	2.83	3.23	4.7	5.4
8th	0.0514	0.0046	5.25	0.47	8.75	0.8
Cumulative ..	0.5554	0·4816	56·71	48.77	94.6	81.3

TABLE II—*contd.*

2·60% NH_4 NO_3 + 40% Gypsum.
Wt. of sample taken=0.9816 gms........1st Set.
Wt. of Sample taken=0.9748 gms........2nd Set.

Days			Increase Wt. gms.		% increase in Wt. on the basis of mixture		% increase in Wt. on the basis of nitrate alone	
			1st Set	2nd Set	1st Set	2nd Set	1st Set	2nd Set
1st	..	..	0.0896	0.1018	9.12	10.4	15.2	17.33
2nd	..	..	..	0.1374	..	14.09	..	23.50
3rd	..	..	0.2606	0.0746	26.55	7.64	44.25	12.74
4th	..	..	0.0396	0.1154	4.04	11.84	6.73	19.73
5th	..	..	0.0382	0.0380	3.89	3.897	6.5	6.49
6th	..	..	0.0588	..	5.98	..	9.96	..
7th	..	..	0.0314	0.0116	3.2	1.19	5.33	1.98
8th	..	..	0.0436	0.0160	4.45	1.64	7.4	2.73
Cumulative		..	0.5618	0.4948	57.23	50.73	95.4	84.55

3. 60% NH_4 NO_3 + 40% Grey Kaolin.
Wt. of sample=0.9836 gms........1st Set.
Wt. of sample=0.9826 gms........2nd Set.

Days			Increase Wt. gms.		% increase in Wt. on the basis of mixture		% increase in Wt. on the basis of nitrate alone	
			1st Set	2nd Set	1st Set	2nd Set	1st Set	2nd Set
1st	..	..	..	0.1603	..	16.36	..	27.27
2nd	..	..	0.4588	0.2232	46.65	22.72	77.75	37.9
3rd	..	..	0.0994	0.1142	10.1	11.62	16.85	19.37
4th	..	..	0.0562	0.0544	5.712	5.537	9.52	9.23
5th	..	..	0.0334	0.0668	3.39	6.798	5.65	11.33
6th	..	..	0.0252	..	2.562	..	4.27	..
7th	..	..	0.0080	0.0630	0.8132	6.41	1.355	10.7
8th	..	..	0.0136	0.0036	1.382	0.3664	2.3	0.61
Cumulative		..	0.6946	0.6855	70.6	69.8	117.67	116.41

TABLE II—*contd.*

4. 60% N H_4 NO_3+ 40% white *Kaolin.*

Wt. of sample=0.9816 gms.........1st Set.

Wt. of sample=0.9918 gms.........2nd Set.

Days	Increase Wt. gms.		% increase in Wt. on the basis of mixture		% increase in Wt. on the basis of nitrate alone	
	1st Set	2nd Set	1st Set	2nd Set	1st Set	2nd Set
1st	..	0.2028	..	20.43	..	34.04
2nd	0.4106	0.2104	41.82	21.1	69.7	35.17
3rd	0.1172	0.1082	11.39	10.9	19.9	18.17
4th	0.0560	0.0496	5.705	4.997	9.51	8.33
5th	0.0364	0.0410	3.708	4.13	6.18	6.9
6th	0.0268	..	2.73	..	4.55	..
7th	0.0306	0.0544	3.117	5.48	5.195	9.13
8th	0.013	0.0002	..	..	..	..
Cumulative ..	0.6726	0.6664	69.00	67.14	115	111.9

5. 60% NH_4 NO_3 + 40 % Chalk.

Wt. of sample=0.9508 gms.

Days	Increase in Wt. gms.	% increase in Wt. on the basis of mixture	%increase in Wt. on the basis of nitrate alone
1st	0.1354	14.24	23.7
2nd	0.1326	13.95	23.17
3rd	0.0816	8.582	14.3
4th	0.0650	6.836	11.4
5th	0.0150	1·587	2.63
6th	..	..	..
7th	0.0378	3.976	6.63
8th	0.0082	0.8626	1.438
Cumulative ..	0.4758	50.03	83.37

6. 60% $NH_4 NO_3$ + 40% Infusorial Earth.
Wt. of sample=0.9910 gms.

Days	Increase in Wt. gms.	% increase in Wt. on the basis of mixture	% increase in Wt. on the basis of nitrate alone
1st	0.1882	19.00	31.66
2nd	0.2240	22.6	37.66
3rd	0.0610	6.15	10.25
4th	..	..	..
5th	0.0498	5.03	8.4
6th	0.0104	1.05	1.75
7th	0.0262	2.64	4.4
8th	0.0922	9.3	15.5
Cumulative ..	0.6518	65.77	109.61

7. 60% $NH_4 NO_3$ + 35% Gypsum + 5% Plaster of Paris.
Wt. of sample=0.9982 gms.

Days	Increase in Wt. gms.	% increase in Wt. on the basis of mixture	% increase in Wt. on the basis of nitrate alone
1st	0.4770	47.85	79.75
2nd	0.0960	9.62	16.03
3rd	0.0608	6.09	10.15
4th	0.0482	4.84	8.07
5th	0.0182	1.822	3·037
6th	—0.0100	..	..
7th	0.0126	1.262	2.103
8th	—0.0232	..	..
Cumulative ..	0.7128	71.484	109.14

TABLE III

Mixture	% increase in Wt. after 8 days on the basis of mixture		% increase in Wt. after 8 days on the basis of nitrate alone	
	1st Set	2nd Set	1st Set	2nd Set
Pure NO_3	86·5	83·75	..	..
NO_3+Clay	56·71	48·77	94·6	81·3
NO_3+Gypsum	57·23	50·73	95·4	84·5
NO_3+Chalk	50·02	..	83·37	..
NO_3+Infusorial earth ..	65·77	..	109·61	..
NO_3+Grey Kaolin ..	70·6	69·8	117·67	116·41
NO_3+White Kaolin ..	69·00	67·14	115·00	111·9

TABLE IV

Hygroscopicity Test on 4 hourly basis from
6·30 A.M. to 6·30 P.M. every day

Sample No.	Mixture	Granule size	Initial Wt. gms	Increase in Wt. gms 1st day — Dry Bulb °F			
				10-30 A.M.	2-30 P.M.	6-30-P.M.	10-30 P.M.
				88·2	103	96	99
1	Pure NO_3 ..	—10,22 mesh	0·9984	0·0506	0·0328	0·0237	0·0236
2	NO_3+Gypsum	,,	1·007	0·0592	0·0414	0·0134	0·0280
3	NO_3+Chalk ..	,,	1·0076	0·0394	0·0314	0·0242	0·0166
4	NO_3+Grey Kaolin	,,	1·0036	0·0318	0·0666	0·0810	0·0594
5	NO_3+White Kaolin	,,	0·9924	0·0460	0·0420	0·0527	0·0393
				D.B. 93	99	102	..
6	Double Salt ..	,,	1·0092	0·0704	0·0434	0·0382	..

Sample No.	Mixture	Increase in Wt. gms. 4th day — Dry Bulb °F			
		6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
		81	93	99	102
1	Pure No_3	0·0984	0·0210	0·0212	0·0026
2	NO_3+Gypsum	0·0468	0·0096	0·0172	—0·0196
3	NO_3+Chalk	0·0630	0·0068	0·0252	—0·0256
4	NO_3+Grey-Kaolin	0·0552	—0·0196	—0·0458	—0·0352
5	NO_3+White Kaolin	0·0512	—0·0168	—0·0504	—0·0366
		D.B.81	89	92	84
6	Double Salt	0·0856	0·0134	—0·0044	0·0232

TABLE IV—*contd.*

Increase in Wt. gms 2nd day				Increase in Wt. gms 3rd day			
Dry Bulb °F				Dry Bulb °F			
6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.	6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
84	92·2	102	96	82	93·5	102	96
0·0586	0·0288	0·0180	0·0243	0·1191	0·0420	0·0414	0·0192
0·0496	0·0260	0·0152	0·0112	0·0650	0·0086	0·0064	0·0004
0·0790	0·0242	0·0242	0·0054	0·0816	0·0016	—0·0008	—0·0108
0·1012	0·0238	0·0280	0·0152	0·1276	0·0058	—0·0086	0
0·1124	0·0304	0·0450	0·0098	0·1052	0·0058	—0·0036	—0·0006
91	94·2	105	91	86	92	98	86
0·1974	0·0172	0·0660	0·0310	0·1092	0·0266	0·0212	3·0130

Increase in Wt. gms. 5th day				Increase in Wt. gms. 6th day			
Dry Bulb °F				Dry Bulb °F			
6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.	6 30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
91	94·2	105	91	86	92	98	86
0·0996	—0·0020	0·0200	0	0·0262	0·0108	0·0152	—0·0220
0·0558	0·0028	0·0136	—0·008	0·0286	—0·0006	0·002	—0·0100
0·0502	0·0078	0·0286	0·0020	0·0194	0·0036	—0·0030	—0·0114
0·0092	—0·0068	0·0058	—0·0064	0·0020	—0·0014	—0·0028	—0·0056
0·0104	—0·0048	0·0038	—0·0012	0·0310	—0·0002	—0·0032	—0·0036
75	86	94	89	74	89	99	94
0·1022	0·0202	0·0116	0·0366	0·0650	0·0228	0·0008	0

TABLE IV—*contd.*

Sample No.	Mixture.	Increase in Wt. gms. 7th day — Dry Bulb °F 6-30 A.M. 81	10-30 A.M. 89	2-30 P.M. 92	6-30 P.M. 84
1	Pure NO_3	0·0482	—0·0184	—0·0046	—0·0152
2	NO_3+Gypsum	0·0112	—0·0208	—0·0100	—0·0068
3	NO_3+Chalk	0·0066	0	—0·0194	—0·0102
4	NO_3+Grey-Kaolin	0·0144	—0·0144	—0·027	—0·0012
5	NO_3+White Kaolin	0·0314	—0·0124	—0·0068	0·0002
		76	85	96	98
6	Double Salt	0·0270	—0·0032	0·0014	0·0130

Sample No.	Mixture	% increase in Wt. 2nd day 6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
1	Pure NO_3	5·87	2·88	1·802	2·44
2	NO_3+Gypsum	4·92	2·585	1·50	1·102
3	NO_3+Chalk	7·85	2·405	2·4	0·536
4	NO_3+Grey-Kaolin	10·08	2·37	2·79	1·51
5	NO_3+White Kaolin	11·32	3·06	4·54	0·985
6	Double Salt	19·6	1·7	6·55	3·08

TABLE IV—*contd.*

Increase in Wt. gms. 8th day, Dry Bulb °F				Increase in Wt. gms. 9th day D.B.	%increase in Wt. 1st day			
6-30 A.M. 75	10-30 A.M. 86	2-30 P.M. 94	6-30 P.M. 89	6-30 A.M. 74	10-30 A.M	2-30 P.M.	6-30 P.M.	10-30 P.M.
0·0386	0·0074	—0·0086	0·0066	0·0282	5·07	3·285	2·38	2·64
0·0492	0·0074	—0·0052	0·0046	0·0234	5·89	4·11	1·33	2·79
0·0402	0·0060	0·0020	—0·0060	0·0412	3·91	3·12	2·4	1·64
0·0630	—0·0052	—0·0060	0·0042	0·0442	3·26	6·64	8·05	5·9
0·0222	0·0048	0·0010	0·0140	0·0044	4·64	4·23	5·31	3·96
D.B. 78	93	99	95	D.B. 82				
0·0460	0·0090	—0·0020	—0·0040	—0·0128	6·97	4·3	3·79	..

% increase in Wt. 3rd day				% increase in Wt. 4th day			
6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.	6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
11·91	4·21	4·15	1·95	9·85	2·12	2·13	0·261
6·46	0·857	0·636	0·0398	4·65	0·955	1·71	..
8·1	0·158	..	..	6·26	0·666	2·5	..
12·7	0·577	..	0	5·5	..	..	..
10·6	0·584	..	..	5·12	..	..	..
10·84	2·64	2·2	1·29	8·5	1·33	..	2·3

TABLE IV—*contd.*

Sample No.	Mixture	% increase in Wt. 5th day			
		6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
1	Pure NO_3	9·98	..	2·02	..
2	NO_3+Gypsum	5·55	0·278	1·35	..
3	NO_3+Chalk	4·99	0·775	2·84	0·195
4	NO_3+Grey-Kaolin	0·916	..	0·577	..
5	NO_3+White Kaolin	1·049	..	0·37	..
6	Double Salt	1·018	2·00	1·15	3·63

Sample No.	Mixture	% increase in Wt. 7th day			
		6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
1	Pure NO_3	4·85	..	..	..
2	NO_3+Gypsum ..	1·112	..	..	..
3	NO_3+Chalk	0·655	0	..	..
4	NO_3+Grey-Kaolin ..	1·435	..	..	..
5	NO_3+White Kaolin ..	3·16	..	..	0·021
6	Double Salt	2·68	..	0·138	1·29

TABLE IV—*contd.*

% increase in Wt. 6th day			
6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.
2·63	1·083	1·53	..
2·84	..	0·199	..
1·935	0·358	..	..
0·199	..	..	..
3·2	..	..	..
6·45	2·26	0.0774	..

% increase in Wt. 8th day				% increase in Wt. 9th day
6-30 A.M.	10-30 A.M.	2-30 P.M.	6-30 P.M.	6-30 A.M.
3·87	0·75	..	0·661	2·822
4·9	0·737	..	0·4565	2·33
4·00	0·595	0·197	..	4·1
6·27	..	..	0·418	4·4
2·24	0·484	0·101	1·41	0·444
4·57	0·894	..	..	..

TABLE V

Hygroscopicity Tests as in Table IV shown on a day to day basis

Sample No.	Mixture	Initial Wt. gms.	Increase in Wt. gms. Dry Bulb °F max. min							
			1st	2nd	3rd	4th	5th	6th	7th	8th
			103,80	102,84	102,82	102,81	105,85·5	98,81	92,75	94 75
1	Pure NO_3	0·9984	0·1920	0·1902	0·2010	0·1444	0·0442	0·0520	0·0004	0·0336
2	NO_3+Gypsum	1·007	0·1916	0·1174	0·0622	0·0630	0·0370	0·0026	0·0116	0·0302
3	NO_3+Chalk	1·007	0·1906	0·1354	0·0530	0·0566	0·0578	0·0042	0·0106	0·0432
4	NO_3+Grey Kaolin	1·0036	0·3410	0·1946	0·0524	—0·0914	0·0054	0·0046	0·0198	0·0378
5	NO_3+White Kaolin	0·9924	0·2924	0·1904	0·0528	—0·0934	0·0284	0·0244	0·0032	0·0242
		D.B.°F	102,81	98,81	92,75	94,75	99,74	98,76	99,78	98,82
6	Double Salt	1·0092	0·3494	0·2234	0·1474	0·1344	0·1334	0·0604	0·0506	—0·0098
7	NO_3+Gypsum+Plaster of Paris ..	0·9982	0·4770	0·0960	0·0608	0·0482	0·0182	0·01	0·0126	—0·0232

TABLE V—*contd.*

Sample No.	% Increase in Wt. on the basis of mixture								% increase in Wt. on the basis of Nitrate alone							
	1st	2nd	3rd	4th	5th	6th	7th	8th	1st	2nd	3rd	4th	5th	6th	7th	8th
1	19·3	19·08	20·55	14·45	4·43	5·21	0·041	3·365								
2	19·05	11·68	6·18	6·27	3·68	0·258	1·13	3·00	31·75	19·46	10·3	10·45	6·13	0·43	1·9	5·00
3	18·95	13·48	5·27	5·64	5·75	..	1·033	4·3	31·6	22·46	8·8	9·4	9·6	..	1·72	7·2
4	34·00	19·35	5·21	..	..	0·457	1·97	3·76	56·67	32·25	8·7	..	..	0·76	3·3	6·267
5	29·5	19·2	5·32	..	2·86	2·46	0·322	2·44	49·16	32	8·867	..	4·73	4·1	0·537	4·067
6	34·6	22·2	14·65	13·35	13·27	6·00	5·04	..								
7	47·85	9·62	6·09	4·84	1·822	..	1·262	..	79·75	16·03	10·15	8·067	3·037	..	2·10	..

TABLE V—*contd.*

Sample No.	%Cumulative increase on the basis of mixture	%Cumulative increase on the basis of Nitrate alone
1.	86·426	..
2.	51·248	85·41
3.	54·423	90·7
4.	64·747	107·9
5.	62·202	103·5
6.	109·11	..
7.	71·484	119·19

TABLE VI
Caking Test with Single bags

Mixture	Amount in bag gms.	Size	Size analysis after first 8 days' test.						Size analysis after second 8 days' test					
			+10 mesh		—10+22 mesh		—22 mesh		+10 mesh		—10+22 mesh		—22 mesh	
			gms.	%	gms.	%	gms.	%	gms.	%	gms.	%	gms.	%
Pure NO_3 ..	48	—10+22	15·1	34·2	18·8	42·5	10·25	23·3	23·2	53·5	8·95	20·7	11·15	25·8
NO_3+Gypsum ..	,,	,,	34·7	76·4	6·0	13·2	4·65	10·4	31·9	75·7	3·6	18·1	9·0	20·2
NO_3+Clay ..	..	,,	15	29·3	25·7	50·2	10·4	20·5	22·8	50·6	12·5	27·8	9·7	21·6
Pure NO_3 ..	37	,,	The cake did not loosen up even on dropping 4 times from 3′ height.											
NO_3+Clay ..	,,	,,	8·71	24·2	22·42	62·3	4·88	13·5	13·75	38·2	13·82	38·4	6·82	23·4
NO_3+Gypsum ..	,,	,,	7·49	21·0	13·12	36·6	15·22	42·5	14·13	49·6	4·0	11·1	10·3	39·3
NO_3+Chalk ..	,,	,,	6·57	18·7	19·82	56·3	8·7	24·8	18·65	52·7	1·35	3·8	15·385	43·5
NO_3+Infusorial earth.	26	,,	12·15	48·2	10·2	42·2	2·42	10·6	The cake did not loosen up even on repeated dropping.					
NO_3+Grey Kaolin	48	,,	16·735	36·4	28·572	62·2	0·650	1·4	17·65	38·7	26·3	58	1·47	3·24
NO_3+White Kaolin	,,	,,	15·936	34·6	29·131	63·2	1·013	2·19	The cake did not loosen up even on breaking.					

TABLE VII

Caking Test with Stacked bags

Day	Mixture	Size	Amount in bags gms.	Size Analysis						Cumulative% of original weights
				+ 10 mesh		—10 + 22 mesh		—22 mesh		
				gms.	%	gms.	%	gms.	%	
3rd	Pure NO_3	—10+22	50	6·575	17·05	27·265	70·7	4·745	12·37	77·17
,,	NO_3 + Gypsum	,,	,,	6·565	15	33·765	77·1	3·415	7·8	87·49
,,	NO_3 + White Kaolin	,,	,,	5·525	11·5	40·375	83·7	2·21	4·6	96·22
,,	NO_3 + Grey Kaolin	,,	,,	23·525	50·9	21·685	47	0·985	2·14	92·39
,,	NO_3 + Chalk	,,	,,	6·565	13·5	40·305	82·7	1·805	3·6	97·35
6th	Pure NO_3	,,	,,	5·165	17·7	20·34	69·5	3·72	12·65	58·4
,,	NO_3 + Gypsum	,,	,,	16·495	39·9	21·545	52·1	3·265	7·91	82·61
,,	NO_3 + W. Kaolin	,,	,,	5·695	12·04	37·415	79	4·275	9·03	94·77
,,	NO_3 + G. Kaolin	,,	,,	15·445	31·8	31·735	65·1	1·425	2·93	97·21
,,	NO_3 + Chalk	,,	,,	12·405	29	26·425	61·9	3·945	9·2	85·55
9th	Pure NO_3	,,	,,	7·562	25·2	17·672	58·5	4·84	16·2	60·15
,,	NO_3 + Gypsum	,,	,,	32·442	80·2	6·282	15·5	1·782	4·4	81
,,	NO_3 + W. Kaolin	,,	,,	12·91	25·3	33·65	70·1	2·04	4·3	95·56
,,	NO_3 + Grey Kaolin	,,	,,	21·89	57·75	15·172	39·8	0·832	2·3	75·788
,,	NO_3 + Chalk	,,	,,	26·352	60·8	14·972	34·8	2·04	4·71	86·728
12th	Pure NO_3	,,	,,	7·595	23·3	18·685	57·3	6·315	19·4	65·19
,,	NO_3 + Gypsum	,,	,,	10·945	42·7	10·775	42	3·905	15·25	51·25
,,	NO_3 + W. Kaolin	,,	,,	9·835	27·8	23·895	68·5	1·245	3·56	69·95
,,	NO_3 + G. Kaolin	,,	,,	The cake did not loosen up even on breaking 4 times from 3′ height.						
,,	NO_3 + Chalk	,,	,,	16·425	49	14·075	42	3·015	9·00	67·03

W. Kaolin = White Kaolin.
G. Kaolin = Grey Kaolin.

TABLE VIII

Diluent	Size analysis for experiment	Bulk Density Lbs./cft.	pH of water extract.
Clay	—100+120	83·24	7·2—7·3
Gypsum	Do.	80·93	7·2—7·4
Chalk	—120, +150	72·8	8·0—8·2
White Kaolin	—100, +120	61·2	8·4
Infusorial Earth	Do.	55·49	8·8—8·9
Grey Kaolin	Do.	52	6·8

STUDY ON THE POSSIBILITY OF EMPLOYING VARIOUS DILUENTS INSTEAD OF CHALK IN AMMONIUM NITRATE FERTILIZERS—PART II

Introduction—This report is in continuation of our previous report on the subject and should be read in conjunction with it. This is also in the nature of an interim report since the results reported have only shown the trend of experiments which are still in progress and will take a few more days for completion. Each mixture investigated has been given an alphabetical code number so that the final result can be reported telegraphically with the appropriate code number.

The points brought out in the earlier report have to be reiterated. The results are only comparative amongst various materials and should not be taken as absolute figures. The results of such small scale short-term laboratory tests are also not conclusive and sometimes are not confirmed by long term plant tests. The experiments will have to be carried on a semi large scale on a planned basis for nearly six months to arrive at reliable conclusions. The time factor has been a pressing one in these experiments. The Nangal clays, though despatched from Nangal on 20th April 1955 reached our laboratory only as late as 11th May 1955. Normally it has been our experience that one duplicate batch of experiments takes nearly three weeks. But in view of the urgency we have attempted to streamline the experiments so that comparative data can be obtained for scrutiny. Therefore the report has to be viewed against these shortcomings.

The present series of experiments has been carried out in a hurry in order to obtain some results for immediate consideration of the Fertilizer Production Committee in respect of their report. But the experiments will be repeated and continued on a planned basis by us but unfortunately those results will take time and will not be available immediately. Thus there is no guarantee attached to the reliability of the results presented here which are the outcome of hurried experimentation.

The experiments reported here are:—

1. Experiments on gradual substitution of ammonium sulphate in the double salt by gypsum
2. Experiments on 60 per cent nitrate + 40 per cent Kaolin from Neyveli (new sample) mixture

3. Experiments on 60 per cent nitrate + 14 per cent chalk + 26 per cent gypsum mixture.
4. Experiments on 60 per cent nitrate + 14 per cent chalk + 26 per cent Nangal clay (three samples) still in progress—code Nos. 'A', 'B' and 'C'.
5. Results of experiments on 60 per cent nitrate + 40 per cent Nangal clay will be reported later since they have been started only on 20th May 1955. The code number for this mixture is 'D'.

1. *Procedure*—The various mixtures for experimentation were prepared employing the method described in the previous report.

For the gypsum-substituted double-salt mixture, the nitrate and calculated quantity of sulphate were evaporated together and the adequate quantity of gypsum mixed in with the saturated melt.

The size—10, + 22 was employed in all experiments.

2. For the hygroscopicity tests 5 gms sample were used instead of 1 gm. as before. The samples were exposed to 81 per cent humidity over saturated ammonium sulphate solution. The weight increases were measured over 24 hours periods.

3. For the chalk, gypsum and nitrate mixture and Neyveli Kaolin, both single bag and stacked bags tests were carried out to determine the caking tendency in storage.

For the Nangal clays the experiments are being carried out on the basis of stacked bags only. Single bags tests were carried out on the gypsum-substituted double salt.

4. Bulk densities and PH of water extract have also been measured for the Neyveli and Nangal clays.

Results—Tables I and II embody the results on the gypsum-substituted double salt mixtures. It is observed that for the mixture in which 40 per cent of the 62.25 portion of sulphate is replaced by gypsum which analyses to a nitrogen content of 21.1 per cent, the hygroscopicity characteristics are similar to the double salt and the caking tendencies as evidenced by single bag tests over a period of sixteen days are the best in comparison with double salt and other mixtures.

Tables III and IV embody the results on 60 per cent nitrate + 14 per cent chalk + 26 per cent gypsum mixture.

It is observed that the hygroscopicity of this mixture is favourable compared to chalk-nitrate or gypsum-nitrate mixtures but in respect of the caking tendency there is a tendency towards agglomeration and the antisetting properties are poor compared to nitrochalk or gypsum-nitrate mixture.

Tables V and VI show the results obtained so far with 60 per cent nitrate + 14 per cent chalk + 26 per cent Nangal clay mixtures. Of the four samples sent from Nangal, only three have been received here:

Sample No. 1, Code No. A: Taken from South-east of Poloram Sarai.

Sample No. 3, Code No. B: Taken from area opposite Jawahar Market beyond Nangal Dam.

Sample No. 4, Code No. C: Taken from about half a mile beyond Nangal Dam along Nangal-Hoshiarpur Road.

The bulk density determinations of these clays indicate that their density varies from 80 to 90 lbs cft. as against the low bulk density of the Kaolins. The pH value is high in one instance, 9.2, and this in the case of the lowest bulk density material and all the clays give alkaline

water extracts. The availability and quality of clay at Nangal has to be investigated more thoroughly since we have received only random samples which may not be representative in character. We have also carried out preliminary investigations on the organic matter in these clays and further experiments will be executed to determine this factor. The origin of these clays is from river beds and there is the possibility of the presence of silt and such organic matters in these clays. It may be mentioned here that while preparing the samples with Nangal clay, the product was found to have a tendency to fall to powder more than the other mixtures which have been experimented with so far.

The experiments on these mixtures are still in progress and the results presented are only indicative of the trends.

Tables VII and VIII are the results obtained with a 60 : 40 mixture of nitrate and a new variety of kaolin received from Neyveli. The hygroscopicity characteristics of this mixture is better than previous materials employed though the setting characteristics of this mixture is aggravated quickly on storage. There is a tendency towards agglomeration.

Table IX gives the figures for bulk densities and pH values of water extracts of the Nangal clays and the Neyveli Kaolin.

TABLE I

Hygroscopicity Test of Double Salt (NO_3SO_4) with gradual replacement of SO_4 by Gypsum of −100, +120 mesh.

	%Moisture absorbed day to day									% on basis of nitrate only	% N_2 in the mixture
	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day	8th Day	Cumulative %		
Amb. temp. Max. min. (°F)	101,80	102,83	100,81	95,82	95,82	98,81	98,80	95,81	..	..	..
1. Double Salt	6·5	..	12·1	4·87	4·32	4·15	3·57	2·68	38·19	101	26·4
2. 80% sulphate + 20% gypsum ..	5·17	..	11·06	4·7	4·04	4·73	3·15	2·49	35·34	93·4	23·75
3. 70% sulphate + 30% gypsum ..	7·08	..	11·9	4·82	4·18	4·22	3·84	2·72	37·95	100·2	22·5
4. 60% sulphate + 40% gypsum ..	8·91	..	12·64	4·16	3·96	3·08	2·9	2·65	38·31	101·4	21·1
5. 50% sulphate + 50% gypsum ..	7·6	..	9·56	2·88	6·24	3·15	3·13	3·14	35·70	94·5	19·8
6. 40% sulphate + 60% gypsum ..	6·71	..	14·25	3·34	1·99	1·96	3·32	3·55	35·33	93·5	18·5
7. 30% sulphate + 70% gypsum ..	6·7	..	12·32	3·24	2·86	2·76	3·4	3·6	34·89	92·3	17·2
8. 20% sulphate + 80% gypsum ..	8·0	..	12·92	3·74	2·72	2·36	2·76	3·0	35·50	93·9	15·9

TABLE II

Caking Test of mixtures of Nitrate—sulphate—gypsum: Gradual substitution of sulphate in double salt by gypsum

Weight in each bag=50 gms. of mixture (−10+22)

Screen Analysis after 1st 8 days.

Mixture	%+10	%−10+22	%−22	% recovered
0% Gypsum	29·7	59·4	11	90·66
20% ,, ...	38	58·7	33	97
30% ,, ...	54·8	42·5	2·72	95·56
40% ,, ...	28·4	68·4	3·19	98·56
50% ,, ...	55·2	41·4	3·34	94·31
60% ,, ...	32·2	64·14	3·65	98·6
70% ,, ...	58·1	39·1	2·82	95·5
80% ,, ...	21·85	74·5	3·65	97·04

All the sizes mixed up and again tested for another 8 days.

Mixture	%+10	%−10+22	%−22	% recovered
0% Gypsum	39·5	43·2	17·3	79·18
20% ,, ...	54·1	41·9	3·98	96·44
30% ,, ...	33·4	59·5	7·1	95·58
40% ,, ...	21·4	73	5·65	97·16
50% ,, ...	45·6	47·8	6·55	93·38
60% ,, ...	56·6	40·5	2·92	83·7
70% ,, ...	66·6	30·4	2·94	92·84
80% ,, ...	71	24·8	4·14	59·36

TABLE III

Hygroscopicity Test.

Mixture: 60%Nitrate+14% Chalk+26% Gypsum (from 15-5-55 to 22-5-55.)

	% increase day to day								% increase on basis of NO_3 only.
	1st day	3rd day	4th day	5th day	6th day	7th day	8th day	cumulative upto 8 days %	75·046
Ambient temp. max. min.	107°,89°	106°,89°	105°,86°	102°,89°	98°,89°	96°,83°			
	8·1	20·1	6·75	4·67	3·34	1·95	1·238	46·148	76·91

TABLE IV

Caking Test.

Mixture—NH_4NO_3—60%
Chalk—14%
Gypsum—26%

Screen analysis after 8 days—11-5-55 to 19-5-55.

(a) Single Bag Test.

%+10	%—10+22	%—22	% recovered of original
52·5	42	5·5	85

(b) Stacked Bags Test.

	%+10	%—10+22	%—22	% recovered from original
3rd day 14-5-55	45	48·5	5·6	80
6th day 17-5-55	51	39	10	77
9th day 20-5-55	36·4	39·5	19	96·22

On the 9th day the bags were quite wet when taken out of the storage vessel.

TABLE V(a)

Hygroscopicity test with 60% Nitrate, 14% chalk, 26% Nangal clay.

	% increase in weight on the basis of mixture.							
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Ambient Temp. Max. Min.	102°,89°	89°,89°	96°,83°	95°,83°	97°,86·2°	104°,84°	103°,89°	101°,89°
1. Nangal Clay No. 1—Code No. 'A'	13·98	8·65	6·71	4·54	2·35	3·4	4·15	2·38
2. Nangal Clay No. 3—Code No. 'B'	10·7	10·76	8·64	6·66	4·45	5·16	2·98	3·42
3. Nangal Clay								
No. 4—Code No. 'C'	14·7	8·4	7·35	2·32	4·7	4·17	3·72	

TABLE V(b)

60% Nitrate, 40% Nangal Clay.

	% increase in weight on the basis of mixture.							
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Ambient temp. Max. Min.	95°,83°	97°,86·2°	104°,84°	103°,89°	101°,89°			
1. Nangal Clay. No. 3—Code No. 'D'	6·57	9·33	10·2	6·52	4·61	4·79		

TABLE VI

Caking Test.

Mixture—I	Mixture—II	Mixture—III	Mixture—IV
Code No. 'A'	*Code No. 'B'.*	*Code No. 'C'*	*Code No. 'D'*
NH_4NO_3=60%	NO_3=60%	NO_3=60%	NO_3=60%
Chalk=14%	Chalk=14%	Chalk=14%	Nergal Clay No. 3=40%
Nangal Clay No. 1 =26%	Nangal Clay No. 3=26%	Nangal Clay No. 4=26%	

Weight in each bag=50 gms.
Size=—10+22.

Screen Analysis every 3rd day.
Stacked bag test.

Day.		Code No.	1st fraction %+10	2nd fraction %—10+22	3rd fraction %—22	% recovered
3rd	A	Duplicate	23·15	72·7	4·18	97·64
			25·7	69·1	5·2	95·24
	B	Do.	63·4	33·2	3·3	85·58
			61·5	34·2	4·34	100·54
	C	Do.	62·1	35·1	2·77	92·4
			65·1	31·64	3·24	92·6
	D		43·2	47·65	9·15	75·28
6th	A	Duplicate	40·6	49·6	9·8	86·34
			49·1	44·1	6·82	89·96
	B	Do.	53	40	6·97	75·68
			51·5	41·65	6·87	79·84
	C	Do.	54·6	37·5	7·9	73·86
			59·1	33·8	7·1	76·62
	D		60·5	32·3	7·25	60·44
9th	A	Do.	72	21·4	6·6	47·42 Maxm
			66·7	23·7	9·6	50·34 Caking
	B	Do.	61·6	34·15	4·25	69·16
			64·9	31·60	4·1	64·32
	C			..		
	D					

TABLE VII

Hygroscopicity test of 60% Nitrate+40% Neyveli clay.

	% increase day to day								% cumulative	% on NO_3 basis
	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day		
Ambient temp. max. min. °F ..	93,79	98,83	93,85	97,87	103,88	105,84	109,89·5	110.91		
	7·2	5·6	13·1	6·16	..	8·94	3·52	1·63	46·15	[illegible]

TABLE VIII

Caking Test of 60% Nitrate + 40% Neyveli clay mixture.

Weight taken in each bag=50 gms.,

Size=—10+22

	%+10	%−10+22	%—22	% recovered.
A *Single bag test.*				
	49·9	43·15	6·91	82·43
B *Stacked bag test.*				
3rd day	11·49	85·2	3·36	98·09
6th ,, ...	12·7	85·7	1·75	92·82
9th ,, ...	68·5	27·45	4·13	79·06
12th ,, ...	55·2	36·6	8·18	69·7

TABLE IX

Bulk densities and PH of Nangal and Neyveli clays

Material	Bulk density lbs./cft.	P H
Nangal clay No. (1) A	80·67	9·2—9·3
Nangal clay No. (3) B	87·92	7·6—7·8
Nangal clay No. (4) C	90·57	7·4
Neyveli clay	59·87	8·8

ANNEXURE XI

REPORT OF THE FABRICATION OF CLAY AMMONIUM-NITRATE FERTILIZERS

1. *Scope of this Report*—The Report of the International Commission on the Synthetic Nitrogen Manufacture in Egypt, dealing in para 17 with the production of ammonium-nitrate fertilizers, considers (page 9) the use of various diluents. It was indicated that limestone, the classical and mostly used diluent for ammonium nitrate could be recommended for Egypt too but for one reservation: it would certainly not improve Egypt's alkaline soils. Therefore, the Commission suggested the use of Nile mud as a diluent instead of limestone, a "clay ammonium-nitrate" fertilizer having all the advantages of "nitro-limestone" and at the same time being suitable for improvement of the Egyptian soil. On page 9 of the Report, the Commission recommends that "the use of mud as a diluent must, therefore, be investigated" and points out that "care will have to be taken that the mud is not contaminated with sand—not with more than a trace of organic matter".

Consequently the report must be amplified in this respect as to:

(a) the use of mud as a diluent,

(b) the required nature and quality of the mud, i.e. regarding its contents of organic matter and sand,

(c) the nature and quality of the Nile mud.

As the Statemines have produced large quantities of ammonium-nitrate fertilizer diluted with clay, I have the pleasure to submit in this Report to your perusal our experience in this field with respect to the questions mentioned sub a and b.

Together with the results of your investigations of the nature etc. of the Nile mud (c) these data will enable you to form your opinion.

2. *Reasons for Statemines to produce an Ammonium-nitrate Fertilizer, diluted with Clay*—In 1930 the Statemines started their production of synthetic nitrogen in the form of ammonium sulphate.

Already in 1932 they switched over production from ammonium sulphate to ammonium nitrate, as it had been established that the latter product is to be preferred because of its fertilising qualities.

Contrary to the conditions of the Egyptian soil lime or limestone is the preferable diluent for Holland, as the soil is short of lime.

In 1932, however, patent applications by I. G. Farben prevented Statemines from using carbonate of lime as a diluting agent. When these patent applications were rejected in 1934, they started the production of the lime ammonium-nitrate, which product soon became the main nitrogen fertiliser of Holland.

In the meantime, to be exact covering the period of 1932 till the beginning of 1936, Statemines produced a considerable quantity of an ammonium-nitrate fertilizer, which was diluted by admixing clay instead of lime.

3. *The Experience of Statemines concerning the Use of Clay as a Diluent for Ammonium nitrate*—Statemines in Limburg produced the following quantities of diluted ammonium nitrate fertilizers:—

Year	Clay Ammonium nitrate	Lime Ammonium nitrate
	Tons	Tons
1932	26,201	..
1933	67,985	..
1934	61,276	48,166
1935	34,406	68,066
1936	9,156	116,383
1937	..	132,847
Upto 1948 the total production amounted to	199,024	2,129,454

The experience in the use of clay as a diluent is acquired by producing a quantity of 200,000 tons in a period of about 4 years.

The fabrication of the product caused no difficulties. The mixing of the ammonium nitrate (standard quality) and the clay proved to be easily done and this mixture had a constant homogeneity. It proved to be most advantageous to use clay with particles as fine as possible: this facilitates the mixing and benefits the homogeneity. The mixture can easily be granulated and the granules had a good and fairly equal shape and size. The product was readily sold and could be stocked and transported without caking or losing its free running quality. The whole process proved to be very attractive and was replaced by the lime-ammonium-nitrate production solely because of the preference of the Dutch Farmers for nitro-limestone.

4. *Analysis of the Clay used by Statemines*—The clay used varied in its composition with the quarrying places as appears from the following data, taken from our analysis file:

	%	%
Organic matter	1·9	3·4
SiO_2	81·6	68·2
Al_2O_2	10·3	9·1
Fe_2O_3	3·3	3·1
CaO	0·6	7·7
CO_2	—	5·9

A typical chemical analysis is the following:

	%
Moisture by 105°C	0·35
SiO_2	65·5
$Fe_2O_4+Al_2O_3$	13·5
CaO	8·35
MgO	1·15
CO_2	5·1
Organic matter	1·9
Moisture by 130°C	1·0
Cl	absent
SO_4	,,
K_2O+Na_2O	1·6

The physical data of the clay used are shown in the following typical analysis made by means of a sedimentation test:

	%
Particles below 20 microns	20
Particles from 20—30 microns	25
Particles from 30—40 microns	25
Particles from 40—50 microns	10
Particles from 50—75 microns	18
Particles above 75 microns	2

(1 micron=0·001 mm.)

5. *The Content of Organic Matter of the Clay*—Statemines had to quarry their clay and consequently this clay contained roots of plants etc. This called for special attention to prevent clogging of the apparatus.

In the case clay is not quarried but procured by other means as will be the case in Egypt, no difficulties will be encountered in this respect.

As appears from the analysis comparison, given sub 3 Statemines used clay of different composition. Their experience is that up to about 3 per cent organic matter no difficulties arised during fabrication as well as storage and transport.

6. *The Content of Sand of the Clay*—It is recommended to use a kind of clay with the lowest content of sand in order to limit as much as possible the erosion of the apparatus.

As appears from the physical analysis, given sub 3 the clay used by Statemines, choosing the right clay-bank, contained a very small amount of sand, viz. the greater part of the size above 75 microns and small parts of the next sizes.

Statemines were in the position to compare the wear of their apparatus when producing lime ammonium-nitrate or clay-ammonium-nitrate.

During the production of the latter product the wear was somewhat higher because of the erosion, caused by the content of sand. The content of sand being small, the erosion was within the limits and cost price of the product was not appreciably increased by it.

7. *Conclusions with Respect to the Use of Nile mud*—From the experience of Statemines the fabrication of clay ammonium-nitrate fertilizers can be recommended and production will yield good results when using clay:

1. With particles as fine as possible,
2. With not more than 3 per cent of organic matter,
3. With smallest possible content of sand.

It will be possible to choose a deposit of Nile mud, which will come up to the requirements above mentioned and I advise to ascertain this point by various analysis of Nile mud.

July 28, 1948. ....

Sd VAN AKEN

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ANNEXURE XII

DOUBLE SALT SPECIFICATIONS

(1) Nitrogen content—26 per cent ±0.2 per cent;

(2) Moisture content—not more than 0.3 per cent;

(3) Complete absence of free ammonium nitrate;

(4) Critical relative humidity should not be lower than 62.3 per cent at 30°C; the product must also conform to agreed hygroscopicity tests;

(5) The product must be without sharp edges, preferably spherical, and also uniform (e.g. at least 95 per cent of the product should conform to a certain size range, say, between 2—4 mm);

(6) The product must contain some suitable conditioning agent and should also be coated with material which would retard absorption of moisture and tendency to form hard cakes; and

(7) A suitable caking test should be laid down so as to ensure that when the product cakes under given conditions, the cake is not harder than a cake of "Montan saltpetro" formed under identicol conditions of humidity, temperature, etc.

ANNEXURE XIII

ESTIMATES OF CAPITAL INVESTMENT REQUIRED FOR PLANTS OF DIFFERENT SIZES AT SELECTED LOCATIONS

CAPITAL INVESTMENT

Location — BOMBAY

Capacities

Ammonia	46,000 tons/yr
Nitric acid (100%)	41,000 tons/yr
Double Salt	138,000 tons/yr
Nitrogen	36,000 tons/yr

In lacs of rupees

I. Completely erected plants including all sources such as cooling towers within battery limits services—		
(a) Ammonia plant	347	
(b) Nitric acid plant	68	
(c) Double salt plant, including sulphate plant, storage and bagging.	272	
Total ..	687	687
II. Services—		
Boiler and power plant	18	
Steam and power distribution	13	
Receiving station for outside power	4	
Water treatment and treated water storage	12	
Water distribution	3	
Workshop, instrument shop, fire fighting and first aid station	10	
Total ..	60	60
III. Land, Fencing, Railways, Roads and Offices	20	20
IV. Working Capital	30	30
Total Capital required		797
		or 800

CAPITAL INVESTMENT

Location NEYVELI

Capacities

Ammonia	.. ..	94,000 tons/yr
Nitric acid	.. ..	60,000 tons yr
Double salt	.. ..	200,000 tons/yr
Urea	.. ..	46,000 tons/yr
Nitrogen	.. ..	72,700 tons/yr

In lacs of rupees

I. Completely erected plants including all services such as cooling towers within battery limits—		
(a) Ammonia plant	795	
(b) Nitric acid plant	90	
(c) Double salt including sulphate plant, storage and bagging	330	
(d) Urea plant including storage and bagging	216	
Total ..	1,431	1,431
II. Services—		
Power and steam distribution including other yard piping ..	49	
Workshop, Instrument shop, fire-fighting and first aid ..	14	
Total ..	63	63
III. Land, fencing, Railways, Roads and Offices	26	26
IV. Working Capital	60	60
V. Colony	285	285
Total Capital required ..		1,865

CAPITAL INVESTMENT

Location VIJAYAWADA

Capacities

Ammonia	94,000 tons/yr
Nitric acid	60,000 tons/yr
Double Salt	200,000 tons/yr
Urea	46,000 tons/yr
Nitrogen	72,700 tons/yr

In lacs of rupees

I. Completely erected plants including services such as cooling towers within battery limits—		
(a) Ammonia plant	795	
(b) Nitric acid plant	90	
(c) Double salt plant including sulphate plant, storage and bagging	330	
(d) Urea plant including storage and bagging	216	
Total	1431	1431
II. Services—		
Boiler and power plant	76	
Steam and power distribution	39	
Receiving station for outside power	9	
Water treatment and treated water storage	16	
Water services, pumping station and distribution	32	
Workshop, instrument shop, first aid and fire fighting	14	
Total	186	186
III. Land, fencing, Railways, Roads and Offices	26	26
IV. Working Capital	72	72
V. Colony	292	292
Total capital required		2,007

CAPITAL REQUIREMENTS

Location NEYVELI

Capacities

Ammonia	.. ..	112,000 tons/yr
Nitric acid	.. ..	66,000 tons/yr
Double salt	.. ..	220,000 tons/yr
Urea	.. ..	65,000 tons/yr
Nitrogen	.. ..	86,500 tons/yr

In lacs of rupees

I. Completely erected plant including services such as cooling towers within battery limits—		
(a) Ammonia plant	865	
(b) Niric acid plant	97	
(c) Double salt plant including sulphate plant, storage and bagging	360	
(d) Urea plant including storage and bagging	286	
Total ..	1,608	1,608
II. Services—		
Power and steam distribution	50	
Water distribution	12	
Workshops	15	
Total ..	77	77
III. Land, Fencing, Railways, Roads, etc.	26	26
IV. Working Capital	68	68
V. Colony	300	300
Total Capital required ..		2,079

CAPITAL REQUIREMENT

Location	VIJAYAWADA	
Capacities	Ammonia	112,000 tons/yr
	Nitric acid	66,000 tons/yr
	Double salt	220,000 tons/yr
	Urea	65,000 tons/yr
	Nitrogen	86,500 tons/yr

In lacs of rupees

I. Completely erected plants including services such as cooling towers within battery limits—		
(*a*) Ammonia plant	865	
(*b*) Nitric acid plant	97	
(*c*) Double salt plant including sulphate plant, storage and bagging	360	
(*d*) Urea plant including storage and bagging	286	
Total ..	1,608	1,608
II. Services—		
Boiler and power plant	86	
Power and steam distribution	50	
Receiving station for outside power	15	
Water treatment plant and treated water storage	20	
Water services pumping station and distribution	33	
Workshop etc.	17	
Total ..	221	221
III. Land, fencing, Railways, Roads and Offices	28	28
IV. Working Capital	96	96
V. Colony	307	307
Total Capital required ..		2,260

CAPITAL INVESTMENT

Location	NEYVELI	
Capacities	Ammonia	130,000 tons/yr
	Nitric acid	82,500 tons/yr
	Double salt	275,000 tons/yr
	Urea	65,000 tons/yr
	Nitrogen	100,000 tons/yr

In lacs of rupees

I. Completely erected plants including services such as cooling towers within battery limits—		
(a) Ammonia plant	975	
(b) Nitric acid plant	120	
(c) Double salt plant including sulphate plants, storage and bagging	417	
(d) Urea including storage and bagging	286	
Total	1,798	1,798
II. Services—		
Power and steam distribution	66	
Cooling water distribution	15	
Workshop, etc.	17	
Total	98	98
III. Land, fencing, Railways, Roads and offices	28	28
IV. Working Capital	78	78
V. Colony	315	315
Total Capital required		2,317

CAPITAL INVESTMENT

Location	VIJAYAWADA	
Capacities	Ammonia	130,000 tons/yr
	Nitric acid	82,500 tons/yr
	Double salt	275,000 tons/yr
	Urea	65,000 tons/yr
	Nitrogen	100,000 tons/yr

In lacs of rupees

I. Completely erected plants including services such as cooling towers within limits—		
(a) Ammonia plant	975	
(b) Nitric acid plant	120	
(c) Double salt plant including sulphate plant storage and begging	417	
(d) Urea plant including storage and bagging	286	
Total ..	1,798	1,798
II. Services—		
Boiler and power plant	101	
Power and steam distribution	66	
Receiving station for outside power	15	
Water treatment plant and treated water storage	25	
Water services, pumping station and distribution	40	
Workshops	17	
Total ..	264	264
III. Land, fencing, Railways, Roads and Offices	28	28
IV. Working Capital	106	106
V. Colony	322	322
Total Capital required ..		2,518

CAPITAL INVESTMENT

Location ITARSI

Capacities

Ammonia	.. ..	83,500 tons/yr
Nitric acid	.. ..	75,000 tons/yr
Double salt	.. ..	250,000 tons/yr
Nitrogen	.. ..	65,000 tons/yr

In lacs of rupees

I. Completely erected plant including services such as cooling towers within battery limits—		
(a) Ammonia plant	752	
(b) Nitric acid plant	110	
(c) Double salt plant including sulphate plant, storage and bagging—	385	
Total ..	1,247	1,247
II. Services—		
Boiler and power plant	405	
Power and steam distribution	34	
Water treatment and treated water storage	32	
Water services pumping station and distribution	89	
Workshop etc.	12	
Total ..	572	572
III. Land, fencing, Railways, Roads and Offices etc.	23	23
IV. Working Capital	57	57
V. Colony	300	300
VI. Additional Railways to connect factory and collieries with main line	20	20
Total Capital required ..		2,219

CAPITAL INVESTMENT

Location — NANGAL

Capacities

Ammonia	.. ..	90,000 tons/yr
Heavy water	.. ..	7·5 tons/yr
Nitro Clay	.. ..	340,000 tons/yr
Nitrogen	.. ..	70,000 tons/yr

In lacs of rupees

I. Completely erected plants—		
(a) Ammonia plant including electrolysis plant and heavy water plant.	1,000	
(b) Nitric acid plant	260	
(c) Nitro clay plant including storage and bagging	250	
Total ..	1,510	1,510
II. Services—		
Steam and water distillation plant	80	
Water pumping station and water distribution	75	
Receiving station for outside power	40	
Power and steam distribution	25	
Water treatment and treated water storage plant	15	
Workshop, instrument shop, fire fighting and first aid plant ..	20	
Machinery and wagons for handling clay	20	
Total ..	275	275
III. Land, fencing, Railways, Roads and Offices	55	55
IV. Working Capital	100	100
V. Colony and temporary living accommodation during construction of the factory.	250	250
Total Capital required ..		2,190

ANNEXURE XIV

ESTIMATED COSTS OF PRODUCTION OF END-PRODUCTS IN PLANTS OF DIFFERENT SIZES AT SELECTED LOCATIONS

COST OF PRODUCTION

Location Bombay

Production Ammonia 46,000 tons/yr

Cost elements	Units	Consumption per ton ammonia	Unit cost	Cost per ton Ammonia Rs.
Raw material				
Refinery gas (2000 BTU/cft)	1000 cft.	16.4	Rs. 3.04	49.8
Process materials				
Process materials *including catalyst* ..	..	..	..	14.2
Utilities				
Steam	Self sufficient			
Power	Kwh	2,150	Pies 6.6	74.0
Treated water replacement for cooling tower	1000 gals	3.0	Rs. 1.5	4.5
Labour and supervision	..	..	..	12.2
Overheads 90% of labour	..	..	..	11.0
Services at 1.3 % of capital cost of plant ..	..	..	..	9.7
Maintenance materials at 3·5 % cost of plant	..	..	..	26.2
Depreciation at 10% of cost of plant ..	..	..	..	75.1
Interest at 4·5% of total capital	..	..	..	35.0
Cost of production per ton ammonia ..	..	..	..	311.7

Capital cost of the plant .. .. Rs. 347 lakhs.
Working capital .. .. .. Rs. 12 lakhs.
Total capital .. .. .. Rs. 359 lakhs.

COST OF PRODUCTION

Location — Bombay

Production — Sulphate-nitrate (Double salt) 138,000 tons/yr

Cost elements	Unit	Consumption per ton double salt	Unit cost	Cost per ton double salt Rs.
Raw Materials—				
Ammonia	tons	0.0334	Rs. 311.7	104.0
Gypsum (97% $CaSO_4 2H_2O$)	tons	0.89	Rs. 35.0	31.2
Process materials *including catalyst* ..	..	..	..	1.7
Utilities—				
L. P. Steam	tons	0.68	Rs. 7.0	4.76
Power by-product	kwh	76	pies 5.9	2.33
Purchased	kwh	48	pies 6.6	1.65
Treated water for cooling tower ..	1000 galls.	5.4	Rs. 1.5	8.1
Labour and Supervision	..	..	..	6.4
Overheads 90% of labour	..	..	..	5.7
Services at 2.5% of capital cost of plant ..	..	..	..	6.16
Maintenance materials at 2.6% of capital cost	..	..	..	6.40
Depreciation at 10% of capital cost ..	..	..	..	24.6
Interest at 4.5% of total capital	..	..	..	11.7
Bagging Charges including bags	..	..	..	19.5
Cost of production per ton double salt ..	..	..	..	234.20

Capital cost of the plant .. .. Rs. 340 lakhs.
Working capital .. .. .. Rs. 20 lakhs.
Total capital .. .. Rs. 360 lakhs.

COST OF PRODUCTION

Location Neyveli

Production Ammonia 94,000 tons/yr.

Cost elements	Unit	Consumption per ton Ammonia	Unit cost	Cost per ton ammonia Rs.
Raw materials				
Lignite (54% H_2O)	tons	4·14	6·6	27·3
Process materials *including catalyst* ..		..	..	12·5
Utilities				
Steam at 20 ats	tons	0·42	Rs. 2·0	0·84
Steam at 20 psig	tons	1·6	Rs. 1·81	2·90
Power	kwh	2,200	pies 6·25	71·5
Treated water replacement cooling tower	1000 galls.	3·0	Rs. 0·374	1·12
Labour and Supervision	..	..	..	16·7
Overheads 90% of labour	..	..	..	14·8
Services at 1·4% of capital cost	..	..	..	11·9
Maintenance mat ria's at 3% of capital cost..	..	..	..	25·0
Depreciation at 10% of capital cost ..	..	..	..	84·5
Interest at 4·5% of capital cost	..	..	..	39·0
Cost of production per ton ammonia ..	..	..	..	308·16

Capital cost of the plant .. .. Rs. 795 lakhs.
Working capital .. .. .. Rs. 23 lakhs.
Total capital .. .. .. Rs. 818 lakhs.

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COST OF PRODUCTION

Location Neyveli

Production Urea 46,000 tons/yr.

Cost elements	Unit	Consumption per ton urea	Unit cost	Cost per ton urea Rs.
Raw materials				
Ammonia (net)	tons	0·59	Rs.308·16	182·0
CO_2	..	..	..	..
Process Materials	..	..	..	0·5
Utilities				
Steam at 8 ats	tons	1·48	Rs. 1·81	2·68
Power	Kwh.	343	pies 6·25	11·20
Treated water replacement for cooling tower	1000 gal.	1·55	Rs. 0·374	0·58
Labour & Supervision	..	..	..	4·0
Overheads 100% of labour	..	..	..	4·0
Services at 2·5% of Capital cost	..	..	..	12·25
Maintenance materials at 3·5% of plant cost	..	..	..	17·15
Depreciation at 10% of plant cost ..	..	..	..	49·0
Interest at 4·5% of total capital	..	..	..	22·6
Bagging charges including bags	..	..	..	22·0
Cost of production per ton Urea ..	..	..	..	327·95
or say ..	..	..	..	328·0

Capital cost of the plant .. Rs. 225 lakhs.
Working Capital .. .. .. Rs. 7 lakhs.
Total Capital .. .. Rs. 232 lakhs.

COST OF PRODUCTION

Location Neyveli

Production Sulphate-nitrate (Double salt) 200,000 tons/yr.

Cost elements	Unit	Consumption per ton double salt	Unit cost	Cost per ton double salt Rs.
Raw materials				
Ammonia	tons	0·334	Rs.308·16	103·0
Gypsum (85%)	tons	1·01	Rs. 35·0	35·35
Process materials	..	..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 1·81	1·23
Power	Kwh.	124	pies 6·25	4·04
Treated water replacement for cooling tower	1000 galls	5·4	Rs. 0·374	2·02
Labour & Supervision	..	..	..	5·4
Overheads at 90% of labour	..	..	..	4·8
Services at 2·5% of capital cost	..	..	..	5·25
Maintenance material at 2·6% of capital cost	..	..	..	5·47
Depreciation at 10% of capital cost ..	..	..	..	21·0
Interest at 4·5% of total capital	..	..	..	10·1
Bagging charges including bags	..	..	..	19·5
Cost of production per ton double salt ..	..	..	..	218·86

Capital cost of the plant .. .. Rs. 420 lakhs.
Working capital .. .. .. Rs. 30 lakhs.
Total capital .. .. Rs. 450 lakhs

COST OF PRODUCTION

Location Vijayawada

Production Ammonia 94,000 tons/yr.

Cost elements	Unit	Consumption per ton ammonia	Unit cost	Cost per ton ammonia Rs.
Raw materials				
Coal	tons	1·85	Rs. 29·0	53·7
Process materials	..	..	..	12·5
Utilities				
Steam at 20 ats	tons	0·42	Rs. 8·8	3·7
Steam at 20 psig	tons	1·6	Rs. 7·5	12·0
Power by-product	Kwh	180	pies 5·6	5·25
Purchased	Kwh	2020	pies 6·0	63·2
Treated water replacement for cooling tower	1000 galls	3·0	Rs. 0·75	2·25
Labour & Supervision	..	..	..	16·5
Overheads at 90% of labour	..	..	..	14·8
Services at 1·4% of capital cost	..	..	..	11·9
Maintenance material at 3% of capital cost ..	..	..	..	25·3
Depreciation at 10% of capial cost	..	..	..	84·5
Interest at 4·5% of capital cost	..	..	..	39·6
Cost of production per ton ammonia ..	..	..	..	345·20

Capital cost of the plant .. .. Rs. 795 lakhs.

Working capital .. .. .. Rs. 30 lakhs.

Total capital .. .. .. Rs. 825 lakhs.

COST OF PRODUCTION

Location — Vijayawada

Production — Urea — 46,000 tons/yr.

Cost elements	Unit	Consumption per ton Urea	Unit cost	Cost per ton Urea Rs.
Raw materials				
Ammonia	tons	0·59	Rs. 345·2	204·0
CO_2	..	..	..	..
Process materials	..	..	..	0·5
Utilities				
Steam at 8 ats	tons	1·48	Rs. 7·5	11·1
Power by-product	Kwh	165	pies 5·6	4·81
Purchased	Kwh	178	pies 6·0	5·56
Treated water replacement for cooling tower.	1000 galls	1·55	Rs. 0·75	1·16
Labour and Supervision	..	..	..	4·0
Overheads	..	..	..	4·0
Services at 2·5% of capital cost	..	..	..	12·25
Maintenance materials at 3·5% of capital cost	..	..	..	17·15
Depreciation at 10% of capital cost ..	..	..	..	49·0
Interest at 4·5% of capital cost	..	..	..	22·6
Bagging charges including bags	..	..	..	22·0
Cost of production per ton Urea ..	..	..	..	358·13

Capital cost of the plant .. .. Rs. 225 lakhs.

Working capital .. .. .. Rs. 7 lakhs.

Total capital .. .. .. Rs. 232 lakhs.

COST OF PRODUCTION

Location Vijayawada

Production Sulphate-nitrate (Double salt) 200,000 tons/yr.

Cost elements	Unit	Consumption per ton Double Salt	Unit cost	Cost per ton Double Salt Rs.
Raw materials				
Ammonia	tons	0·334	Rs. 345·2	115·2
Gypsum (87%)	tons	0·99	Rs. 46·5	46·0
Process materials		..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 7·5	5·1
Power by-product	Kwh	76	pies 5·6	2·2
Purchased	Kwh	48	pies 6·0	1·5
Treated water replacement for cooling tower.	1000 galls	5·4	Rs. 0·75	4·05
Labour and Supervision	..	..	..	5·4
Overheads 90% of labour ..		..	..	4·8
Services 2·5% of capital cost	..	..	..	5·25
Maintenance materials at 2·6% of capital cost	..	..	..	5·47
Depreciation at 10% of capital cost ..	..	..	..	21·0
Interest at 4·5% of total capital	..	..	..	10·0
Bagging charges including bags	..	..	..	19·5
Cost of production per ton double salt ..	..	..	..	247·17

Capital cost of the plant .. .. Rs. 420 lakhs.

Working capital .. .. .. Rs. 35 lakhs.

Total capital .. .. .. Rs. 455 lakhs.

COST OF PRODUCTION

Location	Neyveli	
Production	Ammonia	112,000 tons/yr.

Cost elements	Unit	Consumption per ton ammonia.	Unit cost	Cost per ton Ammonia Rs.
Raw materials				
Lignite (54% H_2O) ..	tons	4·14	Rs. 6·6	27·3
Process materials				
including catalyst	..	..	..	12·5
Utilities				
Steam at 20 ats	tons	0·42	Rs. 2·0	0·84
Steam at 20 psig	tons	1·60	Rs. 1·81	2·90
Power	Kwh	2200	pies 6·25	71·50
Treated water replacement for cooling tower.	1000 galls	3·0	Rs. 0·374	1·12
Labour and Supervision	..	..	..	16·0
Overheads 90% of labour	..	..	..	14·4
Services 1·4% of capital cost	..	..	..	11·1
Maintenance materials at 3% capital cost ..	..	..	..	23·7
Depreciation 10% of the capital cost ..	..	..	..	79·0
Interest at 4·5% of the total capital ..	..	..	..	36·8
Cost of production per ton ammonia ..	..	..	..	297·16

Captial cost of the plant	Rs. 885 lakhs.
Working Capital .. .	Rs. 30 lakhs.
Total Capital ..	Rs. 915 lakhs.

COST OF PRODUCTION

Location — Neyveli

Production — Urea — 65,000 tons /yr.

Cost elements	Unit	Consumption per ton Urea	Unit cost	Cost per ton Urea Rs.
Raw materials				
Ammonia	tons	0·59	Rs.297·16	175·0
CO_2				
Process materials	..	..	..	0·5
Utilities				
Steam at 8 ats	tons	1·48	Rs. 1·81	2·68
Power	Kwh	343	pies 6·25	11·20
Treated water replacement for cooling tower.	1000 gls.	1·55	Rs. 0·371	0·58
Labour and Supervision	..	..	..	3·50
Overheads at 100% of Labour	..	..	..	3·50
Services at 2·5% of the capital	..	..	..	11·0
Maintenance materials at 3·5% of capital cost	..	..	..	15·4
Depreciation at 10% of capital cost ..	..	..	.	44·0
Interest at 4·5% of capital cost	..	..	..	20·4
Bagging charges including bags	..	..	..	22·0
Cost of Production per ton Urea ..	..	..	.	309·76

Capital cost of the plant	Rs. 286 lakhs
Working capital	Rs. 8 lakhs
Total Capital	Rs. 294 lakhs

COST OF PRODUCTION

Location — Neyveli

Production — Sulphate-nitrate (Double salt) — 220, 000 tons/yr.

Cost elements	Unit	Consumption per ton Double salt..	Unit cost	Cost per ton double salt Rs.
Raw materials				
Ammonia	tons	0·334	Rs.297·16	99·0
Gypsum (85%)	tons	1·01	Rs. 35·0	35·35
Process materials				
including catalyst	..	..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 1·81	1·23
Power	Kwh	124	pies 6·25	4·04
Treated water replacement for cooling tower	1000 gls.	5·4	Rs. 0·371	2·02
Labour and Supervision	..	..	..	5·0
Overheads at 90% of Labour	..	..	..	4·5
Services at 2·5% of capital cost	..	..	..	5·2
Maintenance materials at 2·6% of capital cost	..	..	..	5·4
Depreciation at 10% of capital cost ..	..	..	..	20·8
Interest at 4·5% of total Capital	..	..	..	9·96
Bagging charges including bags	..	..	..	19·5
Cost of production per ton double salt	..	..	..	213·7

Capital cost of the plant .. .. Rs. 457 lakhs.

Working Capital .. .. .. Rs. 30 lakhs

Total Capital .. .. .. Rs. 487 lakhs.

COST OF PRODUCTION

Location Vijayawada

Production Ammonia 112,000 tons/yr.

Cost elements	Unit	Consumption per ton Ammonia	Unit cost	Cost per ton ammonia Rs.
Raw materials				
Coal	tons	1·85	Rs. 29·0	53·7
Process materials *including catalysts* ..	..	..	..	12·5
Utilities				
Steam at 20 ats	tons	0·42	Rs. 8·8	3·7
Steam at 20 psig	tons	1·6	Rs. 7·5	12·0
Power by-product	Kwh	180	pies 5·6	5·25
Purchased	Kwh	2020	pies 6·0	63·2
Treated water replacement for cooling tower.	1000 galls	3·0	Rs. 0·75	2·25
Labour and Supervision	..	..	..	16 0
Overheads 90% of labour	..	..	..	14·4
Services at 1·4% of capital cost	..	..	..	11·1
Maintenance materials at 3% of capital cost ..	..	..	..	23·7
Depreciation at 10 % of capital cost ..	..	..	..	79·0
Interest at 4·5% of total capital	..	..	..	37·0
Cost of Production per ton Ammonia	..	..	..	334·0

Capital cost of the plant .. .. Rs. 885 lakhs.

Working capital .. .. .. Rs. 38 lakhs.

Total capital .. .. .. Rs. 923 lakhs

COST OF PRODUCTION

Location Vijayawada

Production Urea 65,000 tons/yr.

Cost elements	Unit	Consumption per ton Urea	Unit cost	Cost per ton Urea Rs.
Raw materials				
Ammonia	tons	0·59	Rs. 334	197·0
CO_2	tons	..	..	..
Process materials				0·5
Steam at 8 ats.	tons	1·48	Rs. 7·5	11·1
Power by-product	Kwh	165	pies 5·6	4·81
purchased	Kwh	178	pies 6·0	5·56
Treated water replacement for cooling tower ..	1000 galls	1·55	Rs. 0·75	1·16
Labour and Supervision		..	..	3·5
Overheads 100% of labour		..	..	3·5
Services at 2·5% of capital cost		..	..	11·0
Maintenance materials at 3·5% of capital ..		..	..	15·4
Depreciation at 10% of the capital cost ..		..	..	44·0
Interest at 4·5% of capital cost		..	..	20·4
Bagging charges including bags		..	..	22·0
Cost of production per ton Urea ..		..	..	339·93

Capital cost of the plant .. .. Rs. 286 lakhs

Working capital .. .. .. Rs. 8 lakhs

Total capital .. .. Rs. 294 lakhs

COST OF PRODUCTION

Location Vijayawada

Production Sulphate—Nitrate (Double salt) 220,000 tons/yr.

Cost elements	Unit	Consumption per ton double salt	Unit cost	Cost per ton double salt Rs.
Raw materials				
Ammonia	tons	0·334	Rs. 334	111·5
Gypsum (87%)	tons	0·99	Rs. 46·5	46·0
Process materials		..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 7·5	5·1
Power by-product	Kwh	76	pies 5·6	2·2
purchased	Kwh	48	pies 6·0	1·5
Treated water replacement for cooling tower ..	1000 galls	5.4	Rs. 0·75	4·05
Labour and Supervision		..	..	5·0
Overheads—90°/。 of Labour		..	..	4·5
Services 2·5% of capital cost		..	..	5·2
Maintenance materials 2·6% of capital cost ..		..	..	5·4
Depreciation 10% of capital cost		..	..	20·8
Interest 4·5% of capital cost		..	..	10·4
Bagging charges including bags		..	..	19·5
Cost of production per ton double salt ..				242·85

Capital cost of the plant	Rs. 457 lakhs
Working capital	Rs. 50 lakhs
Total capital	Rs. 507 lakhs

COST OF PRODUCTION

Location   Neyveli

Production   Ammonia   130,000 tons/yr.

Cost elements	Unit	Consumption per ton Ammonia	Unit cost	Cost per ton Ammonia Rs.
Raw materials				
Lignite (54% H_2O)	tons	4·14	Rs. 6·6	27·3
Process materials *including catalyst* ..		..	..	12·5
Utilities				
Steam at 20 ats	tons	0·42	Rs. 2·0	0·84
Steam at 20 psig	tons	1·6	Rs. 1·81	2·90
Power	kwh	2,200	pies 6·25	71·5
Treated water replacement for cooling tower	1000 galls	3·0	Rs. 0·374	1·12
Labour and Supervision		..	..	16·0
Overheads at 90% of labour		..	..	14·4
Services 1.4% of capital cost		..	..	10·5
Maintenance materials 3% of capital cost ..		..	..	22·5
Depreciation at 10% of capital cost ..		..	..	75·0
Interest at 4·5% of total capital		..	..	34·8
Cost of production per ton ammonia ..		..	..	289·36

Capital cost of the plant	Rs. 975 lakhs
Working capital	Rs. 30 lakhs
Total capital	Rs. 1,005 lakhs

COST OF PRODUCTION

Location Neyveli

Production Urea 65,000 tons/yr.

Cost elements	Unit	Consumption per ton Urea	Unit cost	Cost per ton Urea Rs.
Raw materials				
Ammonia	tons	0·59	Rs.289·36	170·8
Process materials		..	..	0·5
Utilities				
Steam at 8 ats	tons	1·48	Rs. 1·81	2·68
Power	Kwh	343	pies 6·25	11·2
Treated water replacement cooling tower ..	1000 galls	1·55	Rs. 0·371	0·58
Labour and Supervision		..	..	3·5
Overheads 100% of labour		..	..	3·5
Services at 2·5% of capital cost		..	..	11·0
Maintenance Materials at 3·5% of capital cost		..	..	15·4
Depreciation at 10% of capital cost ..		..	..	44·0
Interest at 4·5% of total capital		..	..	20·4
Bagging charges including bags		..	..	22·0
Cost of production per ton Urea ..		..	..	305·56

Capital cost of the plant	Rs. 286 lakhs
Working capital	Rs. 8 lakhs
Total Capital	Rs. 294 lakhs

COST OF PRODUCTION

Location Neyveli

Production Sulphate-nitrate (Double salt)2 75,000 tons/year

Cost elements	Unit	Consumption per ton double salt	Unit cost	Cost per ton double salt Rs.
Raw materials				
Ammonia	tons	0.334	Rs.289·36	96·5
Gypsum (85%)	tons	1.01	Rs. 35·0	35·35
Process materials *including catalyst* ..		..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 1·81	1·23
Power	Kwh	124	pies 6·25	4·04
Treated water replacement for cooling tower	1000 galls	5·4	Rs. 0·374	2·02
Labour and Supervision		..	..	4·4
Overheads 90% of labour		..	..	3·96
Services at 2·5% of capital cost		..	..	4·88
Maintenance materials at 2·6% of capital cost		..	..	6·07
Depreciation at 10% of capital cost ..		..	..	19·50
Interest at 4·5% of total capital		..	..	9·45
Bagging charges including bags		..	..	19·6
Cost of production per ton double salt ..		..	..	207·6

Capital cost of the plant	Rs. 537 lakhs
Working capital	Rs. 40 lakhs
Total capital	Rs. 577 lakhs

COST OF PRODUCTION

Location — Vijayawada

Production — Ammonia — 130,000 tons/yr.

Cost elements	Unit	Consumption per ton ammonia	Unit cost	Cost per ton ammonia Rs.
Raw material				
Coal	tons	1·85	Rs. 29·0	53·7
Process Materials		..	..	12·5
Steam at 20 ats	tons	0·42	Rs. 8 8	3·7
Steam at 20 psig	tons	1·6	Rs. 7·5	12·0
Power by-product	Kwh	180	pies 5 6	5·25
purchased	Kwh	2,020	pies 6·0	63·2
Treated water replacement for cooling towers	1000 galls.	3·0	Rs. 0·75	2·25
Labour and Supervision		..	..	16·0
Overheads 90% of labour		..	..	14·4
Services 1·4% of Capital cost		..	..	10·5
Maintenance materials at 3% of capital cost		..	..	22·6
Depreciation at 10% of capital cost ..		..	..	75·0
Interest at 4·5% of total capital		..	..	35·1
Cost of production per ton Ammonia ..		..	..	326·20

Capital cost of the plant	Rs. 975 lakhs
Working capital	Rs. 42 lakhs
Total Capital	Rs. 1,017 lakhs

COST OF PRODUCTION

Location Vijayawada

Production Urea 65,000 tons/yr.

Cost elements	Unit	Consumption per ton Urea	Unit cost	Cost per ton Urea Rs.
Raw materials				
Ammonia	tons	0.59	Rs. 326.2	192.5
CO_2		..	..	..
Process materials	..	..	..	0.5
Utilities				
Steam at 8 ats	tons	1.48	Rs. 7.5	11.1
Power by-product	kwh	165	pies 5.6	4.81
Purchased	kwh	178	pies 6.0	5.56
Treated water replacement for cooling tower	1000 galls.	1.55	Rs. 0.75	1.16
Labour and Supervision		..	..	3.5
Overheads 100% of labour		..	..	3.5
Services 2.5% Capital cost		..	..	11.0
Maintenance materials 3.5% of capital cost ..		..	..	15.4
Depreciation at 10% of Capital		..	..	44.0
Interest at 4.5% total capital		..	..	20.4
Bagging charges including bags		..	..	22.0
Cost of production per ton urea ..		..	..	335.43

Capital cost of the plant .. .. .. Rs. 286 lakhs.
Working Capital .. .. Rs. 8 lakhs.
Total Capital .. .. Rs. 294 lakhs.

COST OF PRODUCTION

Location Vijayawada

Production Sulphate—nitrate (Double Salt) 275,000 tons/yr.

Cost elements	Unit	Consumption per ton Double Salt	Unit Cost	Cost per ton double salt Rs.
Raw Materials				
Ammonia	tons	0·334	Rs. 326·2	109·0
Gypsum (87%)	tons	0·99	Rs. 46·5	46·0
Process Materials	..	..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 7·5	5·1
Power by-product	kwh	76	pies 5·6	2·2
Purchased	kwh	48	pies 6·0	1·5
Treated water replacement for cooling tower.	1000 galls.	5·4	Rs. 0·75	4·05
abour and Supervision		..	..	4·4
Overheads 90% of labour			..	3·96
Services 2·5% of capital cost			..	4·88
Maintenance at 2·6% of capital cost ..			..	5·C7
Depreciation at 10% of capital cost ..		.	..	19·5
Interest 4·5% of total capital		..	..	9·70
Bagging charges including bags		..	..	19·5
Cost of production per ton double salt ..		..	..	236·56

Capital cost of the plant	Rs. 537 lakhs.
Working Capital	Rs. 56 lakhs.
Total Capital	Rs. 593 lakhs.

COST OF PRODUCTION

Location Itarsi

Production Ammonia 83,500 tons/yr.

Cost elements	Unit	Consumption per ton ammonia	Unit cost	Cost per ton ammonia Rs.
Raw Materials				
Coal	tons	1·8	Rs. 20·0	36·0
Process Materials		..	..	12·5
Utilities				
Steam at 20 ats.	tons	0·42	Rs. 7·0	2·94
Steam at 20 psig.	tons	1·6	Rs. 6·0	9·6
Power by-product	kwh	180	pies 5·0	4·67
from conducing units	kwh	2,020	pies 8·3	87·5
Treated water replacement for cooling tower.	1000 galls.	3·0	Rs. 1·0	3·0
Labour and Supervision		..	..	17·2
Overheads 90% of labour		..	..	15·5
Services 1·4% of capital cost		..	..	12·6
Maintenance materials at 3% of capital cost		..	..	27·0
Depreciation at 10% of capital Cost ..		..	..	90·0
Interest at 4·5% of total capital		..	..	41·6
Cost of production per ton ammonia ..		..	..	360·11

Capital cost of the plant .. .. .. Rs. 751 lakhs.

Working Capital .. .. Rs. 22 lakhs.

Total Capital .. .. Rs. 773 lakhs.

COST OF PRODUCTION

Location   Itarsi

Production   Sulphate-nitrate   250,000 tons/yr.

Cost elements	Unit	Consumption per ton double salt	Unit cost	Cost per ton double salt Rs.
Raw materials				
Ammonia	tons	0·334	Rs.360·11	120·0
Gypsum (87%)	tons	0·99	Rs. 32·4	32·1
Process Material		..	..	1·7
Utilities				
Steam at 20 psig	tons	0·68	Rs. 6·0	4·08
Power by-product	kwh	76	pies 5·0	1·98
From conducing sets	kwh	48	pies 8·3	2·08
Treated water replacement for cooling tower.	1000 galls.	5·4	Rs. 1·0	5·4
Labour and Supervision		..	..	4·7
Overheads at 90% of labour		..	..	4·0
Services 2·5% of capital cost		..	..	4·95
Maintenance at 2·6% of capital cost ..		..	..	5·15
Depreciation at 10% of capital cost ..		..	..	19·8
Interest at 4·5% total capital		..	..	9·5
Bagging charges including bags		..	..	19·5
Cost of production per ton double salt ..		..	..	234·94

Capital cost of the plant	Rs. 495 lakhs.
Working Capital	Rs. 35 lakhs.
Total Capital	Rs. 530 lakhs.

COST OF PRODUCTION

Location	Nangal	
Production	Ammonia	90,000 tons/yr.
	Heavy water (D_2O)	7·5 tons/yr.

Cost elements	Unit	Consumption per ton Ammonia	Unit cost	Cost per year lakhs of Rs.
Power	kwh.	$1273 \cdot 5 \times 10^6$	pies 2·6	172
Process Material	..	..	..	[illegible]
Utilities				
Cooling water	1000 galls.	$8 \cdot 1 \times 10^6$	pies 6·0	[illegible]
Labour and Supervision		..	..	[illegible]
Overheads 100% of labour		..	..	[illegible]
Services		..	..	[illegible]
Maintenance material at 3% of plant cost ..		..	..	[illegible]
Depreciation at 10% of plant cost		..	..	[illegible]
Interest at 4·5% total Capital		..	..	[illegible]
Total cost per annum		..	..	[illegible]
Credit for heavy water 7·5 tons at Rs. 10 lakhs per ton.		..	..	75
Net cost per annum for ammonia ..		..	..	[illegible]
Cost per ton ammonia		..	..	[illegible]

Capital cost of ammonia plant including distillation plant.	Rs. 1080 lakhs.
Working capital	Rs. 70 lakhs.
Total capital	Rs. 1150 lakhs.

COST OF PRODUCTION

Location — Nangal

Production — Nitro-clay (Nangal salt) — 340,000 tons/yr.

Cost elements	Unit	Consumption per ton	Unit cost	Cost per ton Nitro clay Rs.
Raw materials				
Ammonia	tons	0·264	Rs. 360	95·0
Clay	tons	0·4	Rs. 6·0	2·4
Process material *including catalyst*		..	..	1·47
Utilities				
Condensate and boiler feed	tons	2·2	Rs. 0·4	0·88
Cooling water	1000 galls.	27	pies 6·0	0·83
Power	kwh.	160	pies 2·6	2·17
Labour and Supervision		..	..	5·3
Overheads at 100% of labour		..	..	5·3
Services 2·1% of capital cost		..	..	3·13
Maintenance materials at 3% of capital cost		..	..	4·5
Depreciation at 10% of capital cost ..		..	..	15·0
Interest at 4·5% of total capital		..	..	7·15
Bagging charges including bags		..	..	19·5
Cost of production per ton nitro-clay (Nangal Salt).		..	..	162·63

Capital cost of the plant .. .. .. Rs. 510 lakhs.

Working capital .. .. Rs. 30 lakhs.

Total capital .. .. Rs. 540 lakhs.

ANNEXURE XV

SUMMARY OF RECOMMENDATIONS

Part A—*Main recommendations*

(1) Following the directive of Government that one of the new fertilizer production units will have to be installed at Nangal in association with a project for the manufacture of heavy water, it is recommended:

(a) that the plant should be designed to produce 70,000 tons of nitrogen per year along with 7½ tons of heavy water;

(b) that the ammonia synthesis process should be based on electrolytic decomposition of water; and

(c) that the end-product should be ammonium nitrate diluted with clay and chalk in the following proportions.

Ammonium nitrate	60%
Clay	26%
Chalk	14%

The nitrogen content of end-product would thus be 21 per cent and its total annual production 340,000 tons.

(2) The recommendations in para (1) are based on the assumptions:

(a) that the required quantity of Bhakra hydro-electric power (160,000 K.W. at a load factor of 90 per cent) can be made available; and

(b) that the power would be cheap enough to warrant adoption of the electrolysis process for ammonia synthesis and that, in any case, the cost of power would not be more than 2.6 pies per unit.

Should it transpire that the supply of the required quantum of power cannot be guaranteed, the adoption of one of the following two solutions should be considered, depending on the amount of minimum firm power supply that can be assured:

(i) to retain the production capacity at 70,000 tons of nitrogen a year but design the plant to achieve a high stream efficiency (say, 98 per cent); and

(ii) to reduce the production capacity from 70,000 tons to 60,000 tons of nitrogen a year.

(3) The production of the balance of 100,000 tons of nitrogen (out of the total target of 170,000 tons which it is desired to achieve by 1961) should be arranged for partly in the form of urea* (65,000 tons per year) and partly in the form of *sulphate-nitrate (275,000 tons per year).

(4) The double salt to be manufactured in the new unit(s) should conform to the specifications given in Annexure XII; and urea production should be associated with the manufacture of double salt so as to permit the adoption of the "once-through" process.

(5) with regard to the number of units at which the required urea and double salt production should be established and their location, the recommendations are:—

(a) if a fair price not exceeding Rs. 3/2/- per thousand cu. ft. can be negotiated for the 2.3 million cu. ft. of refinery gas which

* The nitrogen content of urea and sulphate-nitrate is, respectively, 45 per cent and 26 per cent.

Stanvac are prepared to supply from their oil refinery at Trombay (Bombay) the following plant units should be established;

(i) a unit at Trombay designed to produce 140 tons ammonia per day by processing the available gas and 138,000 tons of double salt per year as the end-product having a nitrogen content of 36,000 tons per year;

(ii) a unit designed to produce 46,000 tons of urea and 200,000 tons of double salt per year (with a total nitrogen content of 72,700 tons per year) at Neyveli in Madras State or, failing Neyveli (in the circumstances explained in sub-para (8) of para 14 of Chapter V), at Vijayawada in Andhra;

(b) if a fair price cannot be negotiated for the Bombay gas, the entire urea and double salt production (with a total nitrogen content of 100,000 tons per year) should be established at Neyveli or, failing Neyveli, at Vijayawada.

(6) With reference to the recommendations in para (5), it is suggested, however, that some increase should be allowed in the production target of 170,000 tons of nitrogen per year so as to bring it closer to the Ministry of Agriculture's estimate of total additional nitrogen requirements by 1961 (250,000 tons of nitrogen per year). Two specific suggestions that are made in this behalf are; (a) in case a fair price can be negotiated for the Stanvac refinery gas, the capacity of the second unit (to be established at Neyveli or, failing Neyveli, at Vijayawada) should be increased by about 14,000 tons of nitrogen per year so that the unit can be designed to produce 65,000 tons of urea and 220,000 tons of double salt per year. The total nitrogen content of the two products would then be 86,500 tons per year; and (b) if on failure to negotiate a fair price for the Stanvac gas, a plant at Bombay has to be ruled out, the target of 100,000 tons nitrogen per year (excluding 70,000 tons nitrogen/year due to be produced at Nangal) should be increased to the minimum extent which would permit the installation of two units at two locations without any sacrifice of the overall economy which it is possible to achieve by concentrating the production of 100,000 tons of nitrogen in a single unit. Assuming that an increase in the production target to this extent will be agreed to, the establishment of the following two units is suggested:

(i) a unit to produce 65,000 tons of urea and 220,000 tons of double salt per year (with a total nitrogen capacity of 86,500 tons a year) at Neyveli or, failing Neyveli, at Vijayawada; and

(ii) a unit to produce 250,000 tons of double salt per year (with a nitrogen capacity of 65,000 per year) at Itarsi in Madhya Pradesh.

(7) Should Government decide to increase the production target up to the full additional requirement of 250,000 tons of nitrogen per year estimated by the Ministry of Agriculture, consideration should be given, in establishing the extra production of 80,000 tons of nitrogen a year, to the production of alternative nitrogenous fertilisers cheaper than double salt, particularly nitro-limestone for which product the three best locations are Rourkela in Orissa (assuming availability of the hydrogen fraction of the steel plant coke oven gas), Mirzapur in Uttar Pradesh and Bhadravati in Mysore.

(8) Indigenous gypsum should be utilised for the sulphur radical required for the manufacture of ammonium sulphate component of double salt. Utilisation of Saurashtra gypsum is recommended for a plant at Bombay; of Trichinopoly gypsum for a plant at Neyveli; and of Rajasthan gypsum for plants at Vijayawada and Itarsi.

(9) Preference is indicated for the partial oxidation process for conversion of Bombay refinery gas; and it is also suggested that to ensure a reasonably high stream efficiency and continuity of operations, the ammonia synthesis plant should be so designed as to be capable of processing both refinery gas and mineral oil fractions or any hydro-carbon stream.

(10) Direct gasification of South Arcot lignite, Singareni coal and Madhya Pradesh coal is recommended for ammonia synthesis at Neyveli, Vijayawada and Itarsi, respectively.

(11) Capital and production costs and requirements of technical personnel of the different plant units recommended are estimated as follows:

TABLE

Location	Plant capacity in terms of tons of end products per annum	Capital costs (in lakhs of rupees)	Production cost per ton of end-product (in rupees)	Total No. of technical personnel
1	2	3	4	5
1. Nangal .	340,000 tons of clay-cum-chalk-nitrate.	2,190	Rs. 162·63 per ton Nangal salt.	700
2. Bombay ..	138,000 tons of double salt.	800	Rs. 234·2 per ton double salt.	537
3. Neyveli ..	46,000 tons of urea and 200,000 tons of double salt.	1,865	Rs. 328 per ton urea Rs. 218·86 per ton double salt.	886
4. Neyveli ..	65,000 tons of urea and 220,000 tons of double salt.	2,079	Rs. 309·76 per ton urea Rs. 213·7 per ton double salt.	926
5. Neyveli ..	65,000 tons of urea and 275,000 tons of double salt.	2,317	Rs. 305·56 per ton urea Rs. 207·6 per ton double salt.	960
6. Vijayawada ..	46,000 tons of urea and 200,000 tons of double salt.	2,067	Rs. 358·13 per ton urea Rs. 247·17 per ton double salt.	947
7. Vijayawada ..	65,000 tons of urea and 220,000 tons of double salt.	2,260	Rs. 339·93 per ton urea Rs. 242·85 per ton double salt.	977
8. Vijayawada ..	65,000 tons of urea and 275,000 tons of double salt.	2,518	Rs. 335·43 per ton urea Rs. 236·56 per ton double salt.	1,021
9. Itarsi ..	250,000 tons of double salt.	2,219	Rs. 234·94 per ton double salt.	905

(12) The Production Managers and Chief Engineers of all new production units (along with their General Managers and Chief Accounts Officers) should be recruited at once. All other technical personnel in managerial category and all supervisory personnel should be recruited within six months of the award of contracts for the supply/erection/commissioning of plant and machinery. Recruitment of skilled workmen should be deferred till the construction of the new units is nearly complete

and an effort should be made to recruit them, as far as possible, from among the construction staff.

(13) A Special Recruitment Board should be set up for recruitment to supervisory ranks and all managerial ranks other than the topmost rank of Superintendents and officers of equivalent status. Three main sources of recruitment to these ranks are indicated, namely,

(i) Sindri organisation; (ii) trained technical personnel from chemical and fertiliser plants in the private and semi-private sector including senior staff engaged on the construction of new plants; and (iii) engineering graduates.

(14) All Indian recruits to managerial ranks should be sent for a short course of training to operating plants overseas by arrangements with the Contractors selected for the erection/commissioning of the new plants. For the training of untrained and partly trained recruits to supervisory ranks, the establishment of special training facilities at Sindri is suggested.

(15) By way of improving transportation facilities, it is suggested—

(a) in case a plant is located at Neyveli.

(i) railway sidings at Ariyalur, which is the rail head for Trichinopoly gypsum should be strengthened;

(ii) Neyveli should, if possible, be connected with the broad gauge system at the nearest point;

(b) in case a plant is located at Itarsi, two rail links each 10 miles long should be provided to give access to the factory site and the Pathakhera coal mines;

(c) in case a plant is located at Vijayawada,

(i) the proposal now under consideration to replace the Masulipatam-Vijayawada-Guntur metre gauge section by broad gauge should be abandoned;

(ii) consideration should be given to the provision of an additional railway bridge on the Krishna;

(d) in any case, steps should be taken, as soon as funds and technical resources permit, for the removal of the standing transportation bottlenecks over the Bhusaval-Igatpuri section of the Western Railway and the Vijayawada-Madras section of the Southern Railway.

(16) A common Fertilizer Board to direct and control all State-owned fertilizer units, old and new, should be established as the first step towards the implementation of the Committee's recommendations. The Board should have a whole-time executive and should consist, among others, of the administrative and technical heads of the different production units. An effort should be made to ensure that the Board functions as a policy Board; and the responsibility for day-to-day management of each unit should be vested in a Committee of management consisting of (i) the administrative head of the unit; (ii) its technical chief; (iii) the Production Manager; (iv) the Chief Engineer; (v) the Commercial and Accounts Chief; and (vi) the Personnel Manager.

(17) A competent firm of Consulting Engineers should be engaged for the Nangal Plant. For other units a Standing Technical Committee should be formed to fulfil to a large extent the functions of Technical Consultants. The Committee should consist of (i) three expert Consultants to be recruited from abroad on three-year contracts, one of them being an expert on technique of heavy water manufacture, another an expert

on technique of urea production and the third an expert on technique of double salt production; (ii) the Production Managers and Chief Engineers of all the new units; and (iii) a few selected technicians drawn from Sindri and elsewhere.

The Consulting Engineers for the Nangal plant should function under the supervision and control of the Standing Technical Committee. It will be for the Standing Technical Committee to decide how far and to what extent and in what respects association of specialist foreign firms should be enlisted for the other units, it being understood that the engagement of any such firm for limited purposes would not detract from the overall responsibility of the Committee for their satisfactory planning, execution and commissioning.

(18) Tenders should be invited, on the basis of specifications drawn up by the firm of Consulting Engineers in the case of Nangal and by the Standing Technical Committee in the case of other units, for each section of each plant. Contracts should be awarded for individual plants or groups of plants not on the basis of turn-key jobs but on the basis of either supply of plant and equipment alone or their supply and erection or in exceptional cases, their supply, erection and commissioning.

(19) Adequate local organisations for individual production units and a headquarters control organisation for the Central Fertilizer Board should be built up as early as possible.

(20) As an interim measure and pending the constitution of the Central Fertilizer Board, the implementation of the immediate programme indicated by the Committee should be entrusted to either a small *ad hoc* committee or, preferably, a Special Officer invested with the necessary status and powers and assisted by competent lieutenants of appropriate rank.

Part B—Subsidiary and incidental recommendations

(1) When the next instalment of indigenous production of artificial fertilizers is planned, the possibility of establishing production of the following chemical fertilisers should be considered:—

(a) nitro-lime-stone suitably treated so as to reduce its hygroscopicity;
(b) ammonium phosphate and nitro-phosphate;
(c) ammonium chloride (in association with manufacture of soda ash);
(d) urea by the partial recycling or by the complete re-cycling process;
(e) liquid ammonia; and
(f) ammoniated super-phosphate.

Suitable locations for a nitro-limestone factory have been indicated in para (7) of Part A. It is suggested that suitable locations for the products mentioned in (b) (c) and (f) would be

(i) Bombay (for phosphatic fertilizers only).
(ii) Neyveli.
(iii) Vijayawada.
(iv) Kothegudium.
(v) Durgapur.

(2) The possibility of securing spare refinery gas from the Burmah-Shell plant at Bombay should be further explored.

(3) The existing pillar-and-stall method of mining in Palana collieries should be replaced by open cut mining in order to ensure maximum exploitation of the reserves.

(4) Wherever possible, ammonia synthesis plants should in future be associated with new steel plants and the availability of at least the hydrogen fraction of steel plant coke oven gas should be secured for ammonia production.

(5) Further intensive explorations should be taken in hand to prove more fully gypsum reserves in the country particularly in Saurashtra and in Trichinopoly district in Madras State. For this purpose, a central gypsum development organisation should be established with head-quarters at a suitable place in Rajasthan and branch organisations in Saurashtra and in Trichinopoly.

(6) The gypsum reserves in Trichinopoly and Saurashtra should be taken on lease by Government or the Fertilizer Board and modern mining methods introduced for their exploitation. Similarly, in the event of a factory being installed at Itarsi, the management of the factory should obtain a lease of the Pathakhera coal reserves from the Madhya Pradesh Government.

(7) To ensure proper utilisation of medium grade Rajasthan gypsum of 80 to 85 per cent. purity (of which the reserves are considerable), a new ammonium sulphate/double salt factory built on the basis of utilisation of Rajasthan gypsum should be designed to process gypsum with an average purity of 82 per cent and a minimum purity of 80 per cent.

(8) Urgent steps should be taken to explore and prove the extent of the valuable pyrites deposits in Son valley in Shahabad district in Bihar.

(9) For the establishment of any major industry in Assam, the first essential requirement is the improvement of communication facilities in the State.

(10) For the exploitation of Singhrauli coal in Uttar Pradesh/Vindhya Pradesh, it is necessary that the area south of Robertsgunj/Churk should be opened up. Road and rail communication should be established up to the site of the Rihand dam in the first place and as soon as possible thereafter, up to the Singhrauli coal fields which should be ultimately connected with Anupur or Chirmiri on the Eastern Railway.

(11) Fuller investigations should be undertaken to prove ground water resources in Bikaner/Palana area in Rajasthan.

(12) If a fair price can be negotiated for the Stanvac gas an early booking should be made of the required quantum of power from the Trombay power plant now under installation by the Tatas.

(13) Three central institutions should be set up under the auspices of the common Fertilizer Board: viz.,

(i) a Central Research and Development Bureau,
(ii) a central drawing and designing office,
(iii) a central fabrication workshop.

Centralisation or at any rate co-ordination of training arrangements should also be considered.

(14) The Standing Technical Committee should study the question of standardisation of plant and equipment and recommend:

(a) the particular categories of equipment which can be usefully standardised; and
(b) the sizes and specifications to be laid down for the selected categories.

(15) Railway freight charges on gypsum should be reduced **and** brought down if possible, to the level of freight on coal.

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